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Corporate culture, management performance measures and the adoption of integrated manufacturing technologies and practices

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CORPORATE CULTURE, MANAGEMENT PERFORMANCE MEASURES AND THE ADOPTION OF INTEGRATED MANUFACTURING TECHNOLOGIES AND PRACTICES

by

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ABSTRACT

This thesis examines the decision criteria used by manufacturing managers to select and implement integrated manufacturing technologies and practices. It questions how well current management performance measures support the competitive objectives of manufactured products.

The results of a literature search support the assertion that manufacturing plant managers will act in a manner that optimizes their individual performance. The thesis proposes that an acute emphasis on traditional performance measures can lead to a dysfunctional de-emphasis of those technologies and practices

1. that are capital intensive,
2. that require a relatively long payback period, or
3. whose *real* benefits are not directly captured by the cost accounting system.

In order to support this proposition, a scenario that characterizes the future manufacturing environment was developed. The scenario describes the challenges associated with attaining enhanced competitiveness through manufacturing excellence and highlights two areas of particular interest. The first is the process of selecting and implementing integrated manufacturing technologies and practices. The second is the manufacturing plant manager's apparent dilemma of competing priorities.

In order to investigate these areas, a pilot study was conducted in which eleven plant managers were interviewed. The objective of the study was to assess a plant

manager's propensity to adopt integrated manufacturing technologies and practices based on:

1. how they would enhance the manager's individual performance, and
2. how they would enhance the competitiveness of the manufactured product.

The results of the pilot study suggest that an acute emphasis on traditional performance measures may dysfunctionally influence in the adoption process. The results are suggestive rather than conclusive due to the small heterogeneous sample obtained for the study. Results from the study also suggest there are three distinct management perspectives regarding integrated manufacturing technologies and practices. These perspectives are associated with the following scenario:

1. In a stable, *mature* market, the manufacturing arm of the business is managed as if it were a *necessary evil*, ie. to minimize its negative potential.
2. An outsider enters the market with a higher quality, lower cost product. Management attempts to make sweeping changes to manufacturing by investing in technology.
3. Management realizes that in order to take full advantage of these integrated manufacturing technologies and practices, the corporate culture and value system must evolve.

Based on these results, three paradigms are suggested to describe the organization's ability to embrace change, and thus management's response to a dynamic competitive environment. A next step in this area would be the design a diagnostic instrument for assessing the fit of performance measures to the manufactured product's competitive objectives.

In order to further this research area a follow-on study is proposed. In this study, the sample population is segregated according to organizational life cycle and the manufactured product's competitive environment.

1 Introduction

This thesis examines the role of managerial performance measures in the process of adopting integrated manufacturing technologies and practices. The literature on manufacturing competitiveness describes a situation where current manufacturing operations are not cost effective, and investments in new technology are not justifiable. Hayes has reported that the measures used to evaluate a manufacturing plant manager's performance can provide inadequate or misleading information and lead to bad decisions.[1]

> Today's managers are making decisions in complex, technology-driven situations where information supplied by their internal management systems is inadequate and often misleading. Existing cost accounting systems and cost management practices do not adequately support the objectives of automated manufacturing. [These systems and practices] do not support justification of new investments in advanced manufacturing technology: they fail to monitor the benefits obtained. They employ performance measurements that often conflict with strategic manufacturing objectives, and they cannot adequately evaluate the important non-financial measures such as quality, throughput, and flexibility.[2]

A plant manager's behavior is influenced by the set of performance measures used to evaluate his/her performance. Two serious problems posed by such influence are that standard performance measures are based on the accounting period rather than the product life cycle[3], and typically do not capture the strategic benefits offered by many integrated manufacturing technologies and practices.

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[1] Robert H. Hayes, et al., Dynamic Manufacturing: Creating the Learning Organization. (New York: The Free Press, 1988), p. 135.

[2] Callie Berliner and James A. Brimson ed., Cost Management for Today's Advanced Manufacturing. (Boston: Harvard Business School Press, 1988), p. 2.

[3] Robert H. Hayes, et al., Dynamic Manufacturing: Creating The Learning Organization. (New York: The Free Press, 1988), p. 133.

A personal example of the dysfunctional behavior caused by ill-conceived performance measures is one where management opts to have a product assembled in a general configuration by a supplier. The "vanilla" product is then brought in-house where it is customized to a customer order. The justification for this method was standard product cost, which is based on the labor and overhead rate. The apparent savings (the difference between $20. per hour charged by the vendor, and a $180. per hour corporate labor & overhead rate) was significant. The problem was that the $180. per hour included the indirect labor to support the supplier. Since the overhead was pooled among several product lines, product cost, as measured by standard cost, appeared to have been reduced. The were several "real" problems that the standard cost model did not capture. These included:

- Customer responsiveness, and quality were compromised.
- The information systems that support in-house assembly did not lend themselves to this sourcing strategy. Thus, the manual effort to support production increased significantly.
- The responsiveness of the total manufacturing system (which includes suppliers) was compromised. Transferring new designs, and product features from Development to Manufacturing took longer.
- The out-of-pocket product cost increased.

Focusing on short-term financial measures may not be appropriate if long-term competitiveness in the marketplace is the ultimate goal. In fact, in striving to meet such financial objectives, long-term competitive objectives may be compromised.[4]

In order to evaluate the severity of this apparent problem, a pilot study was conducted in which eleven plant managers were interviewed. The objective of the study

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[4] The Manufacturing Studies Board, Toward a New Era in U.S. Manufacturing: The Need for a National Vision. (Washington D.C.: National Academy Press, 1986), p. 57.

was to assess a plant manager's propensity to adopt integrated manufacturing technologies and practices based on:

1. how they would enhance the manager's individual performance, and

2. how they would enhance the competitiveness of the manufactured product.

Ideally, the corporation will measure its plant manager's performance in a manner that is consistent with how the plant's manufactured product(s) compete in the marketplace. The study was designed to measure how well management performance measures suggest decisions that support the competitiveness of the manufactured product.

This thesis consists of five sections. The first section outlines the challenges associated with attaining enhanced competitiveness through manufacturing excellence. The second section describes the process of selecting and implementing integrated manufacturing technologies and practices. This section also discusses the manufacturing plant manager's environment and addresses the question of competing priorities. The first and second sections taken together define the future manufacturing environment, and suggest the research question.

The third section defines the research question. The fourth section describes the research method and the design of the pilot study, and describes an initial set of propositions that were examined in the pilot study.

The fifth section describes the results of the study including both direct results related to the research question and observations made during the study. It also suggests opportunities for further research in this area, and the implications of the pilot study for manufacturing practitioners, and corporate managers.

2 The Challenges of Manufacturing Excellence

The literature on manufacturing management suggests a growing awareness among corporate managers that competence in all production-related activities is of critical importance to competitive success. "At the top of many corporate agendas now rests the determination to boost productivity, product quality, and new product innovation."[5] Routine operations decisions can come to limit the range of the corporation's strategic options by binding it with facilities, equipment, and personnel. The complex, dynamic nature of the manufacturing environment poses a number of dilemmas for managers. These include[6]:

- Deciding which alphabet soup of technologies to implement, or which biased vendor or consultant to engage.
- Having to *automate, emigrate, or evaporate* without fully understanding either the complete costs or the complete benefits of complex, expensive automated systems.
- Having a lack of in-house expertise, but being warned that turn-key systems are unacceptable.
- Facing a *you bet your company* situation, or else incrementally adding incompatible islands of automation.
- Deciding which systems should be interconnected and which can stay independent.
- Determining if the new manufacturing systems are production systems or information systems, and if either is worth the cost.

[5] Steven C. Wheelwright, and Robert H. Hayes, "Competing Through Manufacturing," Harvard Business Review, 63, No. 1 (1985), p. 99.

[6] Jack R. Meredith and Marianne M. Hill, "Justifying New Manufacturing Systems: A Managerial Approach," Sloan Management Review, 28, No. 4 (1987), p. 50.

Manufacturing systems, which consist of people, facilities, equipment, processes, materials, and information systems, often represent the bulk of a manufacturing company's human and financial assets. Goldhar and Jelinek report that managers have been slow to acknowledge the critical importance of these systems to the overall performance of their organizations.[7]

Betz has reported that competitive advantage based on manufacturing ability stems from two sources, namely, *Manufacturing Technology*, and *Managerial Integration*.[8] He defines Manufacturing Technology as the knowledge embodied in production processes, and Managerial Integration as the management system for planning and controlling these production processes.

According to these definitions, a primary goal of management is the linking of technological innovation with market opportunities. Integrated manufacturing technologies and practices may be defined as those technologies and practices that provide for, or require cross-functional integration. For example, the effective deployment of assembly robots requires that the assembly be designed within the limitations of the production process. For this to occur, the Development and Manufacturing Engineering functions should work together.

Many of today's integrated manufacturing technologies and practices are not new. The origin of Numerical Control technology can be traced to the twentieth century Jacquard loom that was controlled by punched cards. The practice of *Design for Manufacturability* existed long before the industrial revolution. During the days of European Craft Guilds, the Development Engineer, Manufacturing Engineer, and

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[7] Joel Goldhar, and Mariann Jelinek, "Plan for Economies of Scope: Today's New Manufacturing Technologies Demand a Serious Rethinking of Corporate Strategy," Harvard Business Review, (November-December, 1983), p. 141.

[8] Frederick Betz, Managing Technology: Competing Through New Ventures, Innovation, and Corporate Research (Englewood Cliffs, New Jersey: Prentice-Hall, 1987), p. 147.

Production Worker were one and the same person; the Skilled Craftsman. *Total Quality Control* is not a new concept. A 1909 magazine article reported:

> Study the successful factories, the profit-making stores. They are built on the idea that quality goods is the fundamental of permanent business. To cut costs, to improve processes, to get an increasingly finer product from unchanging raw materials, to give to consumers the benefit of each automatic machine installed - this is good business as well as the only man's game left worth playing.[9]

What is new is the level of sophistication of these technologies and practices. Electronic Data Interchange is used to transfer quality reports from suppliers to their customers. Computer-based Numerical Control, and Electronic Mail systems support Simultaneous Engineering efforts.

Jaikumar has reported that today's sophisticated integrated manufacturing technologies and practices have provided for a drastically altered competitive environment. This new environment is characterized by:[10]

- A sharp focus on intellectual assets as the basis for a company's distinctive competence.
- A heightened emphasis on the selection of the portfolio of projects a company chooses to manage.
- A close attention to the market and to the special competence of process engineers.
- A pointed emphasis on reducing fixed manufacturing costs and the time required to generate new products, processes, and programs.
- An intensification of cost-based competition of manufactured products.

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[9] "Quality," Systems: The Magazine of Business, 10, No. 3 (September, 1906), p. iii.

[10] Ramchandran Jaikumar, "Postindustrial Manufacturing," Harvard Business Review, 64, No. 6 (1986), p. 75.

The model depicted in figure one has been proposed by Goldhar[11] to describe the underlying concepts and resulting manufacturing system characteristics of both traditional and integrated manufacturing environments.

Traditional Technology Contrasted to Computer-Integrated Flexible Manufacturing

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Traditional technology can be described by:

- Economy of scale
- Learning curve
- Task specialization
- Work as a social activity
- Separable variable costs
- Standardization
- Expensive flexibility and variety

Leading to factories that exhibit characteristics of:

- Centralization
- Large plants
- Balanced lines
- Smooth flows
- Standard product design
- Low rate of change and high stability
- Invetory used as a buffer
- "Focused factory" as an organizing concept
- Job enrichment and enlightenment
- Batch systems

In contrast the CIM factory is described by:

- Economy of scope
- Truncated product life cycle
- Multimission facilities
- Unmanned systems
- Joint costs
- Variety
- Profitable flexibility and variety

Leading to factories that exhibit characteristics of:

- Decentralization
- Disaggregated capacity
- Flexibility
- Inexpensive surge and turnaround ability
- Many custom products
- Innovation and reponsiveness
- Production tied to demand
- Fuctional range for repeated reorganization
- Responsibility tied to reward
- Flow systems

Figure 1: **Traditional versus CIM Manufacturing Environment**

These changes in the characteristics of many U.S. manufacturing companies have been brought about through management emphasis of the following operational goals:

- Improved Quality
- Better Resource Management
- Increased Flexibility
- Reduced Inventory
- Reduced Cycle Time
- Reduced Cost

[11] Joel Goldhar, "In the Factory of the Future, Innovation is Productivity." Research Management (March-April, 1986), p. 29.

In order to achieve such goals, companies have invested heavily in automating processes, implementing information systems, and adopting new organizational structures.

This thesis is based on the following two premises:

1. The motivation to adopt and achieve such goals stems from the plant manager's efforts to optimize his/her personal performance, and
2. To frequently the measures used to assess the plant manager's performance do not reflect the competitive objectives of the manufactured product.

Teresko has concluded that the fundamental issue in implementing Computer-Integrated Manufacturing is not technology, but rather managing it - deciding how, when, and whether to implement it.[12] Meeting the competitive objectives of the manufactured product requires a long-term perspective, and a commitment to cultural change within the organization.

2.1 Long-term perspective

"Recent studies of companies over long periods show that the most successful firms maintain a workable equilibrium for several years, but are also able to initiate and carry out sharp, widespread changes when their environments shift."[13] Where some organizations, initiate system-wide, *frame-breaking* changes only after a sustained period of poor performance, others proactively initiate such changes to take advantage of competitive and/or technological developments.

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[12] John Teresko, "CIM: Much More Than Adding Computers," Industry Week (February 9, 1987), p. 48.

[13] Michael L. Tushman, William H. Newman, and Elaine Romanelli, "Convergence and Upheaval: Managing the Unsteady Pace of Organizational Evolution," California Management Review, 29, No. 1 (1986), p. 29.

A pattern of convergence may improve competitiveness where a company's strategies are aligned with its environment. However, the self-reinforcing behavior associated with convergent management contributes to organizational momentum and complacency. Such behavior may have a negative effect on the organization's flexibility and ability to learn. The momentum that is built up during convergent periods breeds a reluctance to change. As a result, most frame-breaking change is put-off until a financial crisis forces a drastic response.

> Directing a frame-breaking upheaval successfully calls for unusual talent and energy. The new mission must be defined, technology selected, resources acquired, policies revised, values changed, organization restructured, people reassured, inspiration provided, and an array of informal relationships shaped.[14]

The solution seems to be in setting a pace or rhythm of organizational convergence/divergence which allows the organization to integrate the new technologies and practices, but not to become complacent in its new environment.

2.2 Commitment to Cultural Change

Attaining enhanced competitiveness through the adoption of integrated manufacturing technologies and practices can be thought of as a journey rather than a destination. A good example of this concept is 3M's "Quality Revolution" philosophy.

> There is no single correct approach to quality improvement. Rather, an organization must define its needs and then work to implement a process that will meet those needs. And, the quality improvement system that is started today will change dramatically during the years to follow. Quality improvement is a discovery

[14] ibid, p. 41.

process, with many different avenues to be explored. The key is building an approach that is based on sound quality concepts, and most importantly, on a commitment to make quality improvement a permanent way of life.[15]

Developing a truly integrated manufacturing environment requires a substantial investment in both technology and organizational learning. Of the four ways of improving productivity that are most often identified:

1. technological innovation,
2. heightened capital investment,
3. better training, education and higher motivation of workers, and
4. improved government - business relationships,

technological innovation, which requires better educated/trained workers, has been credited with the lions share of productivity enhancement in U.S. manufacturing industries. Some studies have indicated that about half the past increase in productivity in the United States has been attributable to technological change, that is, to a combination of scientific and engineering advance that yielded improvements in the way we produce goods and in the know-how of management.[16]

According to Wheelwright and Hayes[17] there are four indicators that can be used to assess a company's attitude toward the competitive role of its manufacturing organization. These are:

- Continual investment in incremental process improvements.
- Reliance on outside suppliers for equipment development.

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[15] Douglas N. Anderson, "The Quality Evolution," 3M Corporation, p. 1

[16] Simon Ramo, The Management of Innovative Technological Corporations (New York: John Wiley and Sons, 1980), p. 223.

[17] Steven C. Wheelwright, and Robert H. Hayes, "Competing Through Manufacturing," Harvard Business Review, 63, No. 1 (1985), p. 100.

- Attention paid to consistency of performance measurement systems, and manufacturing planning and control procedures.
- Cohesiveness among Marketing, Development, and Manufacturing regarding product/process development.

The changing competitive environment challenges the corporate value system and the management performance measures used to communicate the norms and acceptable behavior to the organization. It is imperative that these values and measures evolve to support the competitive objectives of the manufactured products. The following section describes the findings of an extensive literature search that investigated:

- The formulation of manufacturing strategy,
- The management performance measures used to support that strategy, and
- The justification of integrated manufacturing technologies and practices.

Based on this investigation, a model is developed that describes the basis of the plant manager's *apparent dilemma of competing priorities.*

3 Competitive Objectives & the Manufacturing Environment

This section discusses various aspects of the adoption of integrated manufacturing technologies and practices including

- Management performance measures,
- Management skills needed in the *new* manufacturing environment,
- Organizational issues, and
- Justification of emerging technologies.

In order to better understand the role of management performance measures in the adoption of integrated manufacturing technologies and practices, it is useful to understand the process by which corporate strategy is *mapped* into "Requirements to be met by Manufacturing." Skinner[18] has proposed the model, shown in figure two, that depicts the process by which manufacturing policy is determined.

In decision areas including plant & equipment, production planning & control, labor & staffing, product design & engineering, and organization & management, corporate management needs to recognize that trade-offs exist in the development of manufacturing systems. Skinner's model demonstrates how the "Requirements to be met by Manufacturing" should reflect the competitive, economic, and technological aspects of the corporation's markets.

Figure two is a schematic of an orderly process for determining manufacturing policy. The process begins with an analysis of the competitive situation, which identifies opportunities open to the company. The company's skills and resources associated with present manufacturing systems are then appraised. Based on this information, a competitive strategy is formulated. From this strategy, the demands on

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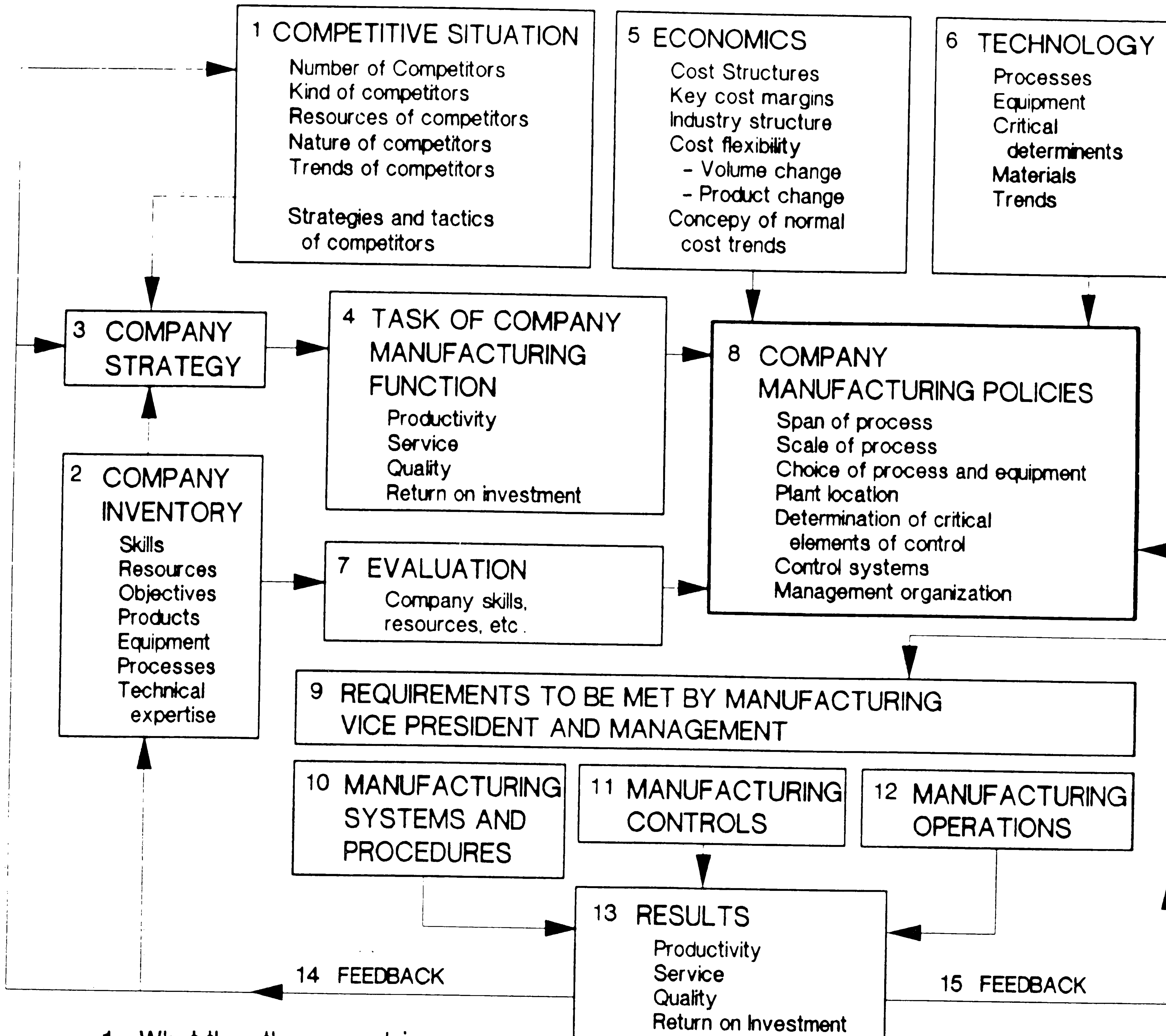
[18] Wickham Skinner, "Manufacturing: Missing Link in Corporate Strategy," Harvard Business Review (May-June, 1969), p. 142.



1. What the others are doing
2. What we have got or can get to compete with
3. How we compete
4. What we must accomplish in manufacturing in order to compete
5. Economic constraints and opportunities common to the industry
6. Constraints and opportunities common to the technology
7. Our resources evaluated
8. How we should set ourselves up to match resources, economics, and technology to meet the tasks required by our competitive strategy
9. The implementation requirements of our manufacturing policies
10. Basic systems in manufacturing (eg. production planning, use of inventories, use of standards, and wage systems)
11. Controls of cost, quality, flows, inventory, and time
12. Selection of operations or ingredients critical to seccess (eg. labor skills, equipment utilization, and yields)
13. How we are performing
14. Changes in what we have got, effects on competitive situation,
15. Analysis and review of manufacturing operations and policies

Figure 2: **Manufacturing Policy Determination**

the manufacturing organization are defined, and any limitations based on economics and technology are identified. These demands and limitations then form the basis of manufacturing policies. The remainder of the model depicts the implementation and feedback from these policies.

The implications associated with defining and communicating the *requirements to be met by manufacturing* are far-reaching.

> Managers can make the manufacturing function a competitive weapon by outstanding accomplishment of one or more of the measures of manufacturing performance. But managers need to know: "What must we be especially good at? Cost, quality, lead times, reliability, changing schedules, new product introduction, or low investment?" [Without a strong signal from corporate management,] professionals in each field attempted to achieve goals which, although valid and traditional in their fields, were not congruent with goals of other areas. The result is complexity, confusion, and worst of all, a production organization which, because it is spun out in all directions by a kind of centrifugal force, lacks focus and a doable manufacturing task.[19]

During the analysis of data from pilot study that was conducted as part of this thesis, an underlying theme emerged that appears to explain the sources of the plant manager's competing priorities and the difficulties of justifying capital investments. This model describes the three major elements that define the environment in which manufacturing managers make decisions. It is presented here (rather then in the analysis section) because it ties together many of the issues presented throughout this thesis, and offers a road map for discussing the pilot study.

Figure three depicts a situation where financial reporting requirements, corporate culture and the competitive strategy influence decisions that define the resulting manufacturing environment. The apparent problem of competing priorities stems from corporate managements weighted emphasis on these areas.

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[19] Wickham Skinner, "The Focused Factory", Harvard Business Review, 1984.

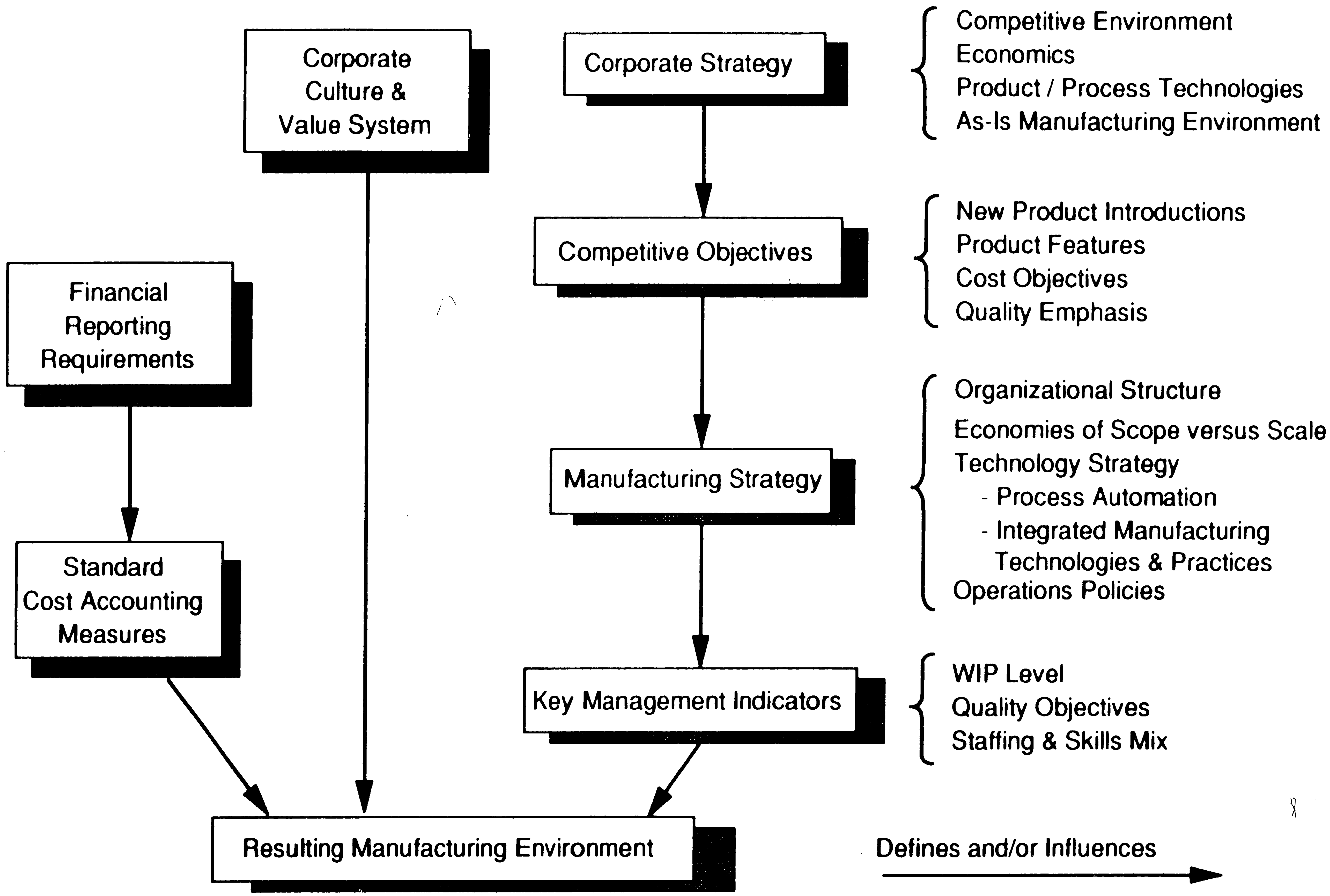

Figure 3: Manufacturing Environment Determination

Of the three sources that determine the resulting manufacturing environment, the corporate culture and value system is the most intangible. Yet, Tom Peter's book "In Search of Excellence" tells us that corporations that have been most successful have strong cultures.

Robert Kaplan has suggested that companies need to adopt a second cost accounting system; one geared toward operations decision-making. In terms of the model developed during this pilot study, this would effectively sever the linkage between internal cost management practices and financial reporting schemes.

The model reflects importance of consistency of the three management subsystems and their implications for management decisions. If the financial reporting, value system, and manufacturing management criteria are consistent with competitive realities, then manufacturing decisions should be supportive of the competitive objectives and enabling of superior managerial performance. If they are not consistent, decisions will be made in an environment of competing priorities that will tend to degrade both the productive unit's and managerial performance.

3.1 Management Performance Measures

> When a [plant] manager decides to favor short-term profits over long-term strategic goals, he has likely been influenced by two considerations. The first, and perhaps more influential, is the manner in which his or her performance is measured by the corporation. The second is a combination of a clear lack of balance between the short and long run as emphasized in corporate communications, linkages between the long-range plan and the operating budget, and the general "culture" of the company.[20]

[20] Robert L. Banks, and Steven C. Wheelwright, "Operations vs. Strategy: Trading Tomorrow for Today," Harvard Business Review, 57, No. 3 (1979), p. 116.

Senior management needs to set long-term goals toward which short-term operations decisions can be directed. Such goals may be stated in terms of reduced order turn-around-time, increased educational level of the work force, tighter quality targets, increased product availability, and enhanced flexibility (in terms of cost and time required to bring new products and product changes to market).

> The mistake of considering low costs and high efficiencies as the key manufacturing objective is typical of the oversimplified concept of *a good manufacturing operation.* A productive system inevitably involves trade-offs and compromises and so must be designed to perform a limited task well, with that task defined by corporate strategic objectives. What is not always realized is that different marketing strategies and approaches to gaining a competitive advantage place different demands on the manufacturing arm of the company.
>
> It is curious that most top managers and production people do not state their yardsticks of success more precisely, and instead fall back on such measures as efficiency, low cost, and productivity. Most managers will readily admit that there are compromises or trade-offs to be made in designing an airplane or a truck. Much the same thing is true of manufacturing. The variables of cost, time, quality, technological constraints, and customer satisfaction place limits on what management can do.[21]

According to Gannon this curiosity may be explained in that managers may not be able to effectively make the connection between corporate strategy and critical operations decisions because of a lack of job-specific knowledge.

> There is evidence that job-specific knowledge bases of many, perhaps most, executives are quite substandard. There are many reasons why managers lack job-specific knowledge. Four of them are: 1) the way managers are selected, 2) the way managers are trained, 3) organizational reward systems, and 4) information overload.
>
> The selection of managers generally appears to be a haphazard process. Management training programs currently available stress the importance of behavioral sensitivity to others and general decision making ability. This movement away from job-specific training increases as organizational level rises. American

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[21] Wickham Skinner, "Manufacturing: Missing Link in Corporate Strategy," Harvard Business Review (May-June, 1969), pp. 136-145.

> organizations have constructed punishment oriented reward systems. [The use of such] reward systems may account for the well-known penchant of American managers to take a short run perspective on problems. Failure to develop the knowledge base can easily lead to making decisions that are poor in the long run because the managers fail to take into account key variables.[22]

Gannon's statement suggests strongly that many managers do not have the insight needed to make decisions based on the competitive environment and are therefore relegated to making decisions based on short-term measures. This view is reinforced by Reich[23] who describes the current turn over of senior corporate management and the glut of corporate acquisitions and mergers as feeding *paper entrepreneurship.* The goal of such paper entrepreneurship is to optimize the parent company's balance sheet rather than maximizing *real* profit.

Given a lack of job or industry-specific knowledge, managers will tend to focus on the common denominator among all companies and all industries, that is, the accounting system.

> Linked to cost-benefit analysis are the motivational aspects of accounting systems. Managers and accountants should give front-and-center attention to predicting how managers will behave under one system verses another. One must appraise the strength of the links between top management goals, management effort, evaluation of performance, and rewards.[24]

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[22] Martin J. Gannon, "Managerial Ignorance," Business Horizons (May-June, 1983), p. 26.

[23] Robert Reich, The Next American Frontier (New York: Penguin Books, 1983), ch. 8.

[24] Kathy Williams, "Renaissance Man," Management Accounting (January, 1986), p. 23.

A recent study investigated a company that manufactures peripheral storage devices for computer systems. The company employs *labor and burden rate* as its key operations performance yardstick.[25] The study reported following behavioral responses:

- Product managers shifted sourcing from internal production to vendors.
- Extreme attention was given to the measurement of direct labor hours.
- Labor intensive processes appeared to be more expensive than capital intensive processes as equipment costs were aggregated into the overhead pool.
- Product managers made no attempt to control rapid growth of support personnel (manufacturing engineering, information systems, test engineering, quality engineering, site services, and financial services) because they never saw the actual costs of these personnel and they would receive only a fraction of the benefits from reducing the cost of these services.

The implications of the measures used to assess management/operations performance have been demonstrated by Ridgway. His view reinforces the assertion that managers will perform in a manner that will optimize the variables being measured.

> There is today a strong tendency to state numerically as many as possible of the variables with which management must deal. Research indicates that indiscriminate use and undue confidence and reliance in them will result from insufficient knowledge of the full effects and consequences. Indiscriminate use may result in side effects and reactions outweighing the benefits. There is no substitute for genuine analysis of all the elements entering into a firm's work. Even where performance measures are instituted purely for purposes of information, they are probably interpreted as definitions of the important aspects of that job or activity and hence have important implications for the motivation of behavior.[26]

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[25] Robert S. Kaplan, "Accounting Lag: The Obsolescence of Cost Accounting Systems," California Management Review (Winter, 1986), pp. 174-199.

[26] V.F. Ridgway, "Dysfunctional Consequences of Performance Measures," Administrative Science Quarterly (September, 1956), pp. 240-147.

There are risks associated with assessing a manufacturing manager's performance based on a predetermined set of numerical indicators or hurdles. These include:

- The chosen set of indicators may not realistically depict the manufacturing environment.
- Conflict (competing priorities) may arise in a set of indicators that approximate the true manufacturing environment, ie. work-in-process inventory versus product availability.
- When performance indicators are based on managerial accounting indicators, the manufacturing manager's focus will be based on the accounting period rather than the product life cycle.

Clearly, there are difficulties in determining appropriate performance measures and cost reporting systems. To make matters worse, these targets (determination of the most appropriate set of indicators) are moving targets.

> Using measures appropriate for one stage of a product's life cycle for products that are in a different stage will lead to dysfunctional behavior. Most commonly, managers introducing new products, but who are evaluated on the basis of cost minimization and productivity, may not be as responsive to customer needs, will freeze the design specifications of the products prematurely in an attempt to standardize production, and not pay sufficient attention to producing consistently high-quality products.[27]

Manufacturing performance measures need to reflect the business strategy of the company and be congruent with both marketing and product development objectives. The critical indicator(s) of success will change dynamically throughout the life of the product. The solution to this dilemma lies in redefining the basis of managerial

[27] Robert S. Kaplan, "Measuring Manufacturing Performance: A New Challenge for Managerial Accounting Research, " The Accounting Review (October 1983), pp. 686-705.

accounting systems and gaining a long-term perspective by adopting a secondary set of operations performance measures that reflect a firm's business strategy and its market's critical success factors.

> The two essential tasks of factory management are to create clarity and order, and to facilitate learning. When plant managers are stuck with poor measures of how they are doing and when a rigid, by-the-book emphasis on standards, budgets, and exception reports discourages the kind of experimentation that leads to learning, the real levers on factory performance remain hidden.[28]

Hayes and Clark go on to suggest clearly identifiable activities that will enhance operations performance that include:

- Improving product structure.
- Smoothing Capacity.
- Improving process yields.
- Increasing worker flexibility.
- Reducing lot sizes and setup times.

> Every manufacturing site is, of course, unique, and no blanket prescription will apply equally to them all. Nevertheless, we do know enough about how manufacturing systems function to be confident that working such levers will take managers in the right direction.[29]

According to Wheelwright[30] the four most important performance criteria are:

Efficiency - This criterion encompasses both cost efficiency and capital efficiency and can generally be measured by such factors as return on sales, inventory turnover, and return on assets.

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[28] Robert H. Hayes, and Kim B. Clark, "Why Some Factories are More Productive Than Others," Harvard Business Review, 64, No. 5 (1986), p. 71.

[29] Larry P. Ritzman, Barry E. King, and Lee J. Krajewski, "Manufacturing Performance - Pulling the Right Levers," Harvard Business Review (March-April 1984), p. 152.

[30] Steven C. Wheelwright, "Reflecting Corporate Strategy in Manufacturing Decisions," Business Horizons (February 1978), p. 61.

Dependability - The dependability of a company's products and its delivery and price promises is often extremely difficult to measure. Many companies measure it in terms of "percent of on-time deliveries."

Quality - Product quality and reliability, service quality, speed of delivery, and maintenance quality are important aspects of this criterion. For many firms, this is easy to measure by internal standards, but as with other criteria, the key is how the market evaluates quality.

Flexibility - The two major aspects of flexibility changes are in the product and the volume. Special measures are required for this criterion, since it is not generally measured.

If the corporation is to meet its competitive objectives, the performance measures used to assess its plants performance will have to be aligned with the competitive objectives of its plants' manufactured products. The appropriateness of these measures is a critical success factor because performance measures define what is important to the plant manager.

> In all persuasion, the most effective appeal is self-interest - the value the listener of your message [plant manager] as well as the overall value to the organization [productive unit]. The overall value to the organization may not be enough. It is difficult to persuade someone to do something, no matter how much it may benefit the organization or others, if it is not in his or her self-interest.[31]

This section has identified management skills as a critical aspect in bridging the gap between corporate strategy and operations-level decision making. The following section further describes the importance of managers job-related skills.

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[31] George deMare, 101 Ways to Protect Your Job: A Handbook on How to Handle Your Most Valuable Asset, Your Job. (New York: McGraw Hill, 1984).

3.2 Managers Skills Needed for the New Manufacturing Environment

The literature suggests that modern manufacturing tools, ie. local area networks, just-in-time logistics, group technology, and programmable logic controllers, will advance the production of both non-technical and technologically sophisticated products. The prudent manager will assume that unusual sensitivity and perception will exist on the part of competitors of the potential technological advance. This makes it incumbent on the manufacturing leadership to be well versed in emerging manufacturing technologies and practices. However, even if management successfully implements such modern manufacturing tools, competitive advantage is not assured. Manufacturing managers must be able to link the benefits of these integrated manufacturing technologies and practices to both market opportunities and the overall business strategy of the firm.

> Some observers argue persuasively that American companies would rather serve existing markets than create new ones, to follow rather than to lead, and to buy existing companies rather than to develop a superior product or process technology. This pattern of behavior requires much less knowledge than a bold, long-term strategy, since the manager does not need to be on top of the latest developments when this approach is used. Failure to develop the knowledge base can easily lead to making decisions that are poor in the long run because the managers fail to take into account key variables.[32]

> . . . the major barrier to the effective use of this new technology is lack of understanding of its impact on strategy. Managers must reinterpret its often considerable costs in light of the expanded options it makes available - and the costs of not adopting it.[33]

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[32] Martin J. Gannon, "Managerial Ignorance," Business Horizons (May-June 1983), p. 29.

[33] Joel Goldhar, and Mariann Jelinek, "Plan for Economies of Scope: Today's Manufacturing Technologies Demand a Serious Rethinking of Corporate Strategy," Harvard Business Review, (November-December 1983), p. 146.

> Companies contemplating *Advanced Manufacturing Technologies* need to give even more thought to the selection and development of manufacturing managers. Future managers will need a broader range of competence than their predecessors. They will have to know the technology and be able to grasp (practically and conceptually) the technical, human, and business aspects of production. They must also be able to anticipate and orchestrate change in the organization.[34]

Thus, the literature suggests that successful implementation of a manufacturing strategy requires leadership beyond that of conventional financial justification. It requires a thorough knowledge of the company's operations, the customer and the competitive environment. Today, manufacturing managers are being penalized by cost accounting and management control practices that were put in place in 1925.[35]

3.3 Organizational Issues

Management of technology cannot be treated separately from management of production. The culture of a manufacturing organization must nurture individuals who can identify and funnel scarce resources toward the technologies and practices that will ensure the competitiveness of the productive unit. Integration is as much an organizational issue as it is a technical issue. While immature technology and justification may be obstacles, organizational difficulties create the hurdle that most companies fail to surmount. Integrating new technology with an existing

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[34] Richard E. Waltman, and Gerald I. Susman, "People Policies for the New Machines," Harvard Business Review, 65, No. 2 (1987), p. 102.

[35] "Is Your Company Ready for Integrated Manufacturing?" Production Engineering (February 1986), p. IM4.

organization means changing the way the organization works, and overcoming organization inertia against doing so.[36]

> In general, the capabilities of any manufacturer are a function of that firm's two major productive elements: its structure and its infrastructure. The firm's "structure" basically consists of its physical plant: its facility, machinery, tools, materials, utilities, and even its physical labor. The infrastructure integrates all the systems in the enterprise to produce the product/service that the market demands. When a firm loses efficiency, or quality, or some other competitive ability, it is rarely the structure that is the problem; rather it is the infrastructure. When such problems are pinned down, they invariably fall at the interfaces between the elements, typically departments, of the organization.[37]

Implementing *Computer Integrated Manufacturing* is not a natural act for a manufacturing organization. Most organizations are designed in islands of authority, with isolated activities conducted by individual departments. In a CIM environment every department is, by definition, highly dependent on each another. Establishing the corporate vision or set of goals needed to migrate the organization toward integration is important because CIM's role goes beyond supporting the manufacturing function. Its ultimate role is to optimize the business. CIM, if implemented successfully requires that each functional area of the organization think beyond its own narrow focus. It can make them realize that goals for individual functions have to be balanced to meet overall objectives."

> Simply investing in new technology or systems guarantees nothing. What matters is how their introduction is managed, as well as the extent to which they support and reinforce continual improvement throughout a factory. Managed right, new

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[36] "Organization Inertia Holds Back CIM," Manufacturing Systems, 5, No. 6 (1987), p. 8.

[37] Jack R. Meredith, "Implementing the Automated Factory," Journal of Manufacturing Systems, 6, No. 1 (1987), p. 10.

> investment supports cumulative, long-term productivity improvement and process understanding - what we refer to as learning.[38]

In order to successfully integrate new technologies into an existing organization, the organization will have to question the way it operates and competes. For bureaucratic organizations, this can be a gut-wrenching experience. This evolutionary process of fitting the new technology into the organization requires what has been termed *organizational learning.*

3.3.1 Building Block Approach

One methodology for managing a CIM program embraces a phased, building block approach; each phase having well defined milestones that are linked to the goals and objectives of the manufacturing organization. These building blocks should address three intertwined areas. These are process enhancements, information and control methods, and organizational issues.

> An important finding for producers of industrial capital goods is that "the focus on new technology has taken a back burner to the first priority of getting the entire plant operation under control. The predominant issues facing management today are producing to quality standards, high and rising overhead costs and timely introduction of new products." Product quality was clearly in the lead in action programs in the 1986 survey. Next ranked were three programs centered in better control and integration of shop operations. By titles, these included Production Control Systems, Statistical Process Control, and Manufacturing Systems Integration.[39]

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[38] Robert H. Hayes, and Kim B. Clark, "Why Some Factories are More Productive Than Others," Harvard Business Review, 64, No. 5 (1986), p. 68.

[39] John D. Baxter, "U.S. Manufacturers Set to Counterattack," Iron Age (November 21, 1986), p. 36.

Along with the idea of simplifying or rationalizing the current operations before implementing emerging technologies, is the concept of determining a balanced emphasis on process, product and integrating technologies.

> The most successful corporations not only take the interactions among the eight critical decision areas (product design, process design, facility and plant configuration, information and control systems, human resources, research and development, suppliers roles and relationships, and organization) into account, they also continually reevaluate and orchestrate their manufacturing decisions to support their strategic goals. Manufacturing changes cannot be made in isolation. Technology's dramatic transformation of the factory has strengthened the link between manufacturing strategy and business strategy - and thereby invalidated a host of time-tested operational principles and decision criteria.[40]
>
> In the new technological society, managers at all levels and in all departments will need to know how to exploit and apply the constant stream of new technological advances that affect them, their products, their services, and their business methods. The universal assumption will be: *There is nothing permanent but change.*[41]

3.4 Justification of New Technologies

The justification for integrated manufacturing technologies and practices should reflect opportunities to sustain market share and/or capture market opportunities.

> How much must a company differentiate its products to gain a decisive competitive advantage? Experience indicates that there is a definable point at which the market will respond to a change in value - a point where an incremental improvement in some value parameter (price, quality, or service) will trigger a disproportionate

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[40] Elizabeth A. Haas, "Breakthrough Manufacturing," Harvard Business Review, 65, No. 2 (1987), p. 80.

[41] F.D. Barrett, "Technology: The Permanent Wave," Business Quarterly, 50, No. 1 (1985), p. 44.

volume increase and tilt the competitive balance. We call this the strategic breakpoint.[42]

The National Association of Accountants has reported that *Return On Investment* justification for new technology based on internal hurdle rates and cost savings are not adequate decision criteria.[43] A more meaningful performance measure is the projected sales growth generated by the benefits of the technology under consideration. Figure four depicts a phenomena where the payback period for new technologies was greater than four years, while the sales increased by more than 15% in the first year. For most plant managers a four year payback period would be unacceptable, while a 15% increase in sales might represent a strategic breakpoint.

This apparent dichotomy between internal performance measures and the competitive environment is a primary focus of CAM-I {Computer Aided Manufacturing International}, and individual researchers including Robert Kaplan, Joel Goldhar, and Steven Wheelwright.

Although this data is based on *product* technology, it is not difficult to conclude that the effect of integrated *process* technologies that affect product quality, and the responsiveness and agility of the manufacturer will be similar. ". . . technologies should be chosen on the basis of their contribution to the firm's competitive strategy and not on just their financial return."[44] The point here is that simple ROI calculations that report cost savings, and do not reflect market opportunities may suggest non-prudent business decisions.

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[42] Elizabeth A. Haas, "Breakthrough Manufacturing," Harvard Business Review, 65, No. 2 (1987), p. 76.

[43] Robert A. Howell, et. al. Management Accounting in the New Manufacturing Environment, Montvale, New Jersey: National Association of Accountants, 1987), ch. 2.

[44] Jack R. Meredith, "Implementing the Automated Factory," Journal of Manufacturing Systems, 6, No. 1 (1987), p. 4.

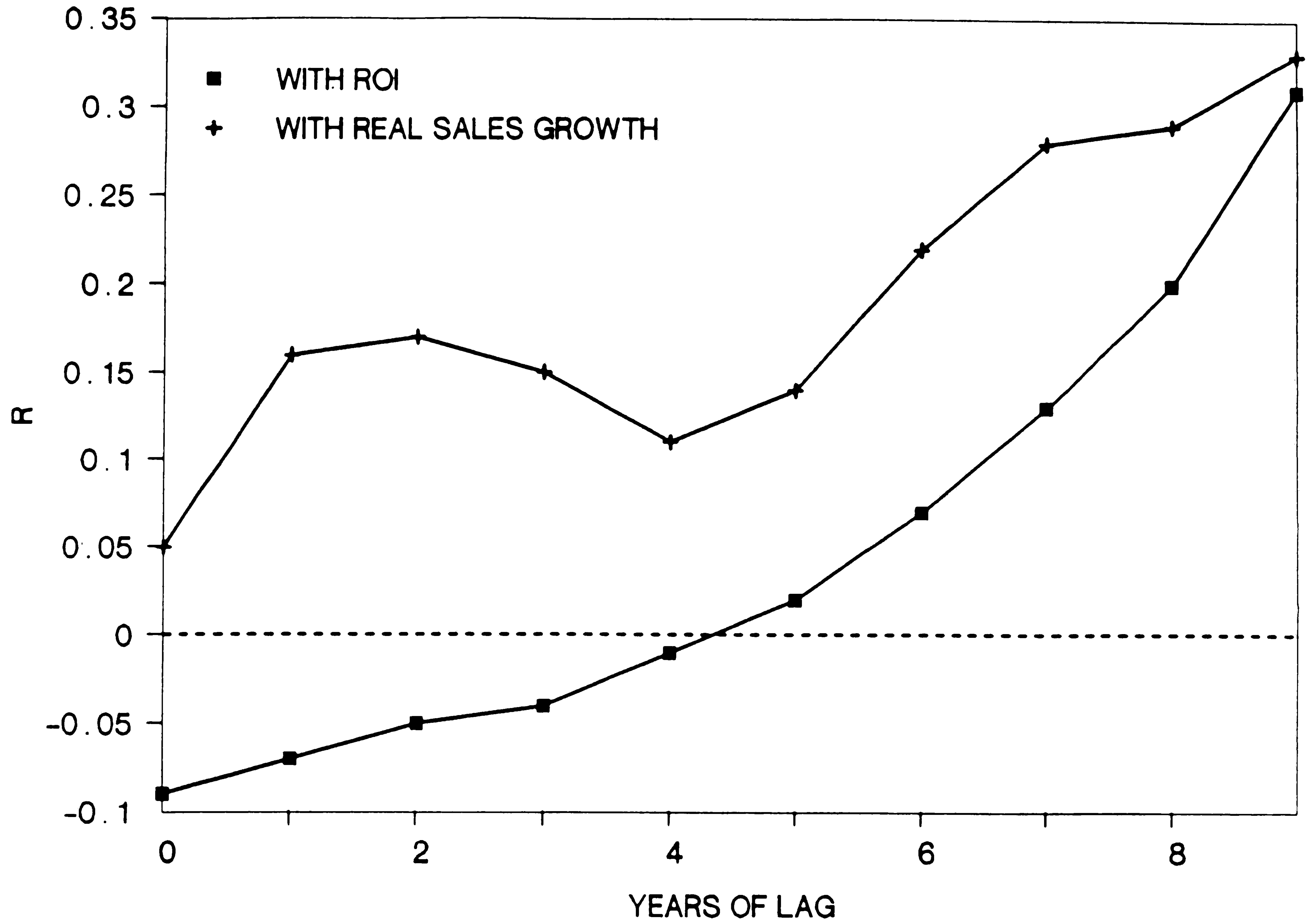

Figure 4: **Lagged Correlations of Product R&D/Revenue With Performance Measures**[45]

The use of return on investment is symptomatic of other, basic conceptual errors in profit center measurement systems. These errors include:[46]

1. The failure to distinguish between techniques used to measure past financial performance and those required to establish future performance objectives.
2. The failure to differentiate between systems that measure the performance of the profit center and those that measure the performance of the managers.

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[45] A presentation entitled "Innovation, Strategy, and Performance," given by Professor Alex Miller (University of Tennessee) at Lehigh University, September 10, 1986.

[46] John Dearden, "Measuring Profit Center Managers," Harvard Business Review, 65, No. 5 (1987), p. 84.

3. The failure to segment variances from the budget by differences in the way that managers can influence them.

> Not all changes facing managers in this new environment are so easy to grasp. It is, for example, much harder to define strategic business units when quite different businesses share a common manufacturing core. As the allocation of manufacturing costs and overhead comes increasingly to depend on transfer pricing, conventional accounting methods like ROI for assessing business performance are of ever more limited usefulness.[47]

According to Dr. John A White, now Associate Director of Engineering at the National Science Foundation, "Factory managers are concerned about being able to sell the integrated manufacturing concept to corporate executives and boards of directors. They can't quantify the synergistic benefits of integrated manufacturing, in which the whole is greater than the sum of its parts."[48] A well-defined manufacturing strategy can become the keystone in determining the appropriate justification model.

> Manufacturing strategy [,which defines goals and objectives of the manufacturing firm, and the plans to achieve those targets,] should be thought of as a proactive weapon in the competitive battle. It is the overall guide to what production will contribute in support of the whole organization.[49]

> At the top level, there should be a regular, annual evaluation of the factors required to succeed in the firm's market. The firm should know what the competitive task is for that market, how it changes, and how, when, and why it will change again. There should also be measures of how well the firm does on those critical success factors. These may not be highly quantitative, or even objective, but they should have been

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[47] Joel Goldhar, and Mariann Jelinek, "Plan for Economies of Scope: Today's Manufacturing Technologies Demand a Serious Rethinking of Corporate Strategy," Harvard Business Review, (November-December 1983), p. 144.

[48] "Is Your Company Ready for Integrated Manufacturing?" Production Engineering (February 1986), p. IM32.

[49] Charles G. Andrew, "Motivation in Manufacturing," Production and Inventory Management, 27, No. 2 (1986), p. 134.

given thought and be collected and analyzed on a regular basis. Common factors might include number of quality complaints per dollar sales, number of patents each year, lead time on products or service parts, life cycle cost of the products, and so on.[50]

The business strategy together with the manufacturing strategy should be flexible enough to accommodate the dynamics of the market, yet sound enough to guide policy making and lower level managerial decisions. The strategy should be well reflected in the day-to-day operations of the company and form the basis for the justification of integrated manufacturing technologies and practices.

[50] Jack R. Meredith, "Implementing the Automated Factory," Journal of Manufacturing Systems, 6, No. 1 (1987), p. 6.

4 The Research Question

The current literature on manufacturing management suggests that the future competitive environment will demand increasing abilities on the part of the manufacturing manager. Managers will need an in-depth understanding of the competitive environment in which the manufactured product competes. They will require the ability to assess the potential risks and benefits associated with a variety of integrated manufacturing technologies and practices. They will also need the *people skills* required to orchestrate the organizational change that is essential to the successful implementation of these technologies and practices.

A major consideration in the adoption of emerging technologies is the linkage between manufacturing operations and corporate management. Even the most skillful manufacturing manager will not be able to effect significant change in the way his organization performs its work if corporate management does not support his effort. A key element of this linkage is the extent to which measures used to assess the manufacturing manager's performance support the competitive objectives of the manufactured product. Ridgway[51] has reported that the measures used to evaluate a manager's performance will profoundly influence the decision-making process.

Figure five is based on the model presented on page 14, and depicts the research area of the study. This scenario suggests the following research question. Do the measures used by corporate management to evaluate plant managers' performance suggest decision-making that supports the long-term competitive objectives of the manufactured product(s)? The following sections discuss the design, administration, and results of a pilot study which was conducted to address this research question.

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[51] V.F. Ridgway, "Dysfunctional Consequences of Performance Measurements." Administrative Quarterly (September, 1956), pp. 240-247.

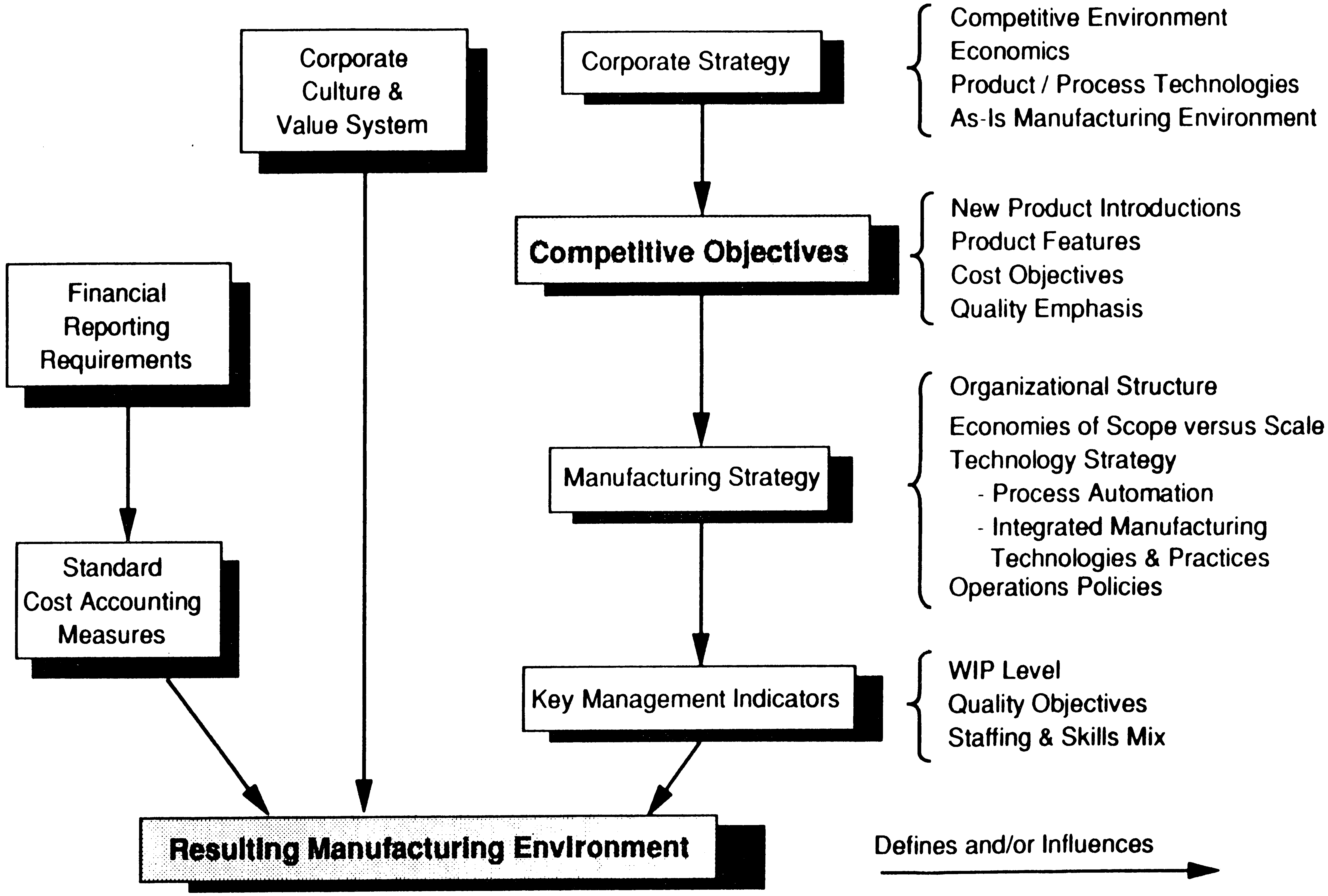

Figure 5: **The Research Area Model**

5 Design and Administration of a Pilot Study

In order to investigate how well performance measures are aligned with competitive objectives, and to address the research question, three preliminary issues needed to be resolved. They were:

1. What position in the corporate organization has the primary responsibility for implementing integrated manufacturing technologies and practices?
2. What is the appropriate business area, or product line to study?
3. What research techniques would be most appropriate for conducting a pilot study?

The plant manager was assumed to be the person most likely to have the primary responsibility in the adoption process, and therefore became the focus of the study. This assumption was challenged using *Responsibility Charting* techniques. Responsibility charting is explained on page 39.

Having determined the appropriate group of people to interview, the second issue was resolved in a straight forward manner. That is, the appropriate business area should be based on the product(s) manufactured at the plant manager's facility. However, many manufacturing plants manufacture numerous products that use different manufacturing processes, and are marketed in different ways to different market niches. For example, a plant may be producing a standard, high volume product that competes on the basis of low cost. It may also produce a highly customized product that is in the early stages of the product life cycle that competes on the basis of function alone. According to Abernathy[52], the relevant unit of study is the *productive unit*, which consists of a given product line, and its associated production processes. Each subject plant manager was therefore asked to focus on a specific productive unit.

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[52] William Abernathy, Kim B. Clark, Industrial Renaissance: Producing a Competitive Future in America (New York: Harper Row, 1983), ch. 2.

Numerous articles have been published on the behavioral aspects of performance measures. Pertinent articles can be found in the management science and cost management literature. The literature suggests that, for many organizations, there are differences between behavior that would optimize the manager's personal performance, and behavior that would support the productive unit's competitive objectives. However, little quantitative data is available to support these assertions. The pilot study was therefore designed to provide data suitable for quantitative analysis. The quantitative analysis would demonstrate how well the corporate value system and management performance measures promote behavior that supports the productive unit's competitive objectives.

Rather than measuring these organizational attributes directly, a catalyst was chosen. The pilot study sought to measure the motivation to adopt integrated manufacturing technologies and practices based on 1) how they would support the productive unit's competitive objectives, and 2) how they would enhance the plant manager's measured performance.

A primary goal in designing the study was to allow for the identification of any competing priorities associated with performance measures and the manufactured product's competitive environment. In doing so, it was decided to focus on the individual plant manager's perspective to determine *"If I do what's 'right' to support the marketplace, will it have a positive or degrading effect on my personal performance?"*

Using a variation of the Q-Sort methodology[53,54], each plant manager was asked to score and rank order a list of integrated manufacturing technologies and practices in terms of 1) Most likely benefit to the productive unit's competitiveness if fully

[53] Kenneth J. Cooper, "The Modified Q Technique in Rural-Urban Field Research," Human Organization, 18, No. 3 (1959), pp. 135-139.

[54] For the original concept of the Q Technique, see William Stephensen (1953). For applications of the technique, see Carl Rogers (1951), and Carl Rogers and Rosalind Dymond (1954).

implemented, and 2) Most likely benefit to the plant manager's performance if implemented in the current manufacturing environment {culture & value system}.

5.1 Initial Propositions and Assumptions

The key variables in the adoption decision process that were considered included:

- The basis by which the manufactured product competes in the marketplace
- Corporate culture and value system
- Formal management performance measures

The study did not attempt to differentiate between behavior based on formal performance measures and that which is based on corporate values[55]. Rather, it lumped them together as <u>internally motivated behavior</u>. In contrast, <u>externally motivated behavior</u> is based on the competitive environment, and the financial and banking environment.

The first assumption of the study was that the adoption of integrated manufacturing technologies and practices is an unnatural act for traditional manufacturing organizations. The motivation for doing so comes from outside the manufacturing organization, e.g. corporate culture, and formal performance measures. One plausible exception to this assumption is the syndrome where an engineer has a elegant solution and is out looking for a problem to solve. The assumption is still valid because the engineer will still have to justify his/her solution in terms of the 'rules' defined by the corporate culture, performance measures, and business environment.

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[55] Terrence E. Deal and Allen A. Kennedy, <u>Corporate Cultures: The Rites and Rituals of Corporate Life.</u> (New York: Addison Wesley, 1982), ch. 2.

The second assumption was that the plant manager is the focal point of the adoption decision process. This assumption was tested by determining the manager's role using responsibility charting techniques where the subject was asked to select from a list of possible roles the one that best described his role in the adoption decision process.

The objective of the study was to demonstrate, quantitatively, any misalignment between the currently employed management performance measures and the productive unit's competitive objectives. The pilot study also attempted to investigate the following propositions:

- Plant managers will act to optimize their individual performance.
- The currently used set of management performance measures tend to sustain the status quo and do not support the concept of integration whether through technology, organizational structure, or the so-called *fifth generation management* ideology described by Savage.[56]

5.2 Design of the Interview

The interview consisted of three phases. Each phase consisted of rank ordering technologies, and competitive areas using Q-Sort techniques. The interview script that was used to conduct the interviews may be found on page 65. The interview consisted of an introduction and three phases. The introduction was compromised of two tasks. The first was to explain the study to the subject plant manager, and to inform him as to his anonymity and the use of the data. The second task was to identify the specific productive unit upon which the interview would focus.

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[56] Charles M. Savage, ed., Fifth Generation Management (Dearborn, Michigan: Society of Manufacturing Engineers Blue Book Series, 1988), p. 19.

The first phase was concerned with assessing how manufacturing supports the competitive objectives of the productive unit. The manager was asked to score and rank order a list of competitive objectives, and then describe how the top three were measured within his organization. A list of these competitive areas can be found on page 45.

The second phase investigated the effects of culture and management performance measures on the plant manager's propensity to adopt integrated manufacturing technologies and practices. The manager was asked to score and rank order a list of integrated manufacturing technologies and practices. Scores were on a scale from 1-7; 1 representing the least benefit. The list of these technologies and practices can be found on page 74. The four parts of this phase were:

1. Determine the manager's role in the adoption process. This included determining the plant manager's knowledge of each technology and practice, and his/her perceived role in its adoption. Participating plant managers were asked to rate his/her understanding of each technology and practice along a scale from one (no knowledge) to six (expert). Each participant was then asked to select from a list of possible roles (shown in figure six), the one(s) that reflect his/her role in the adoption of each technology and practice. Only those technologies and practices for which the participant had <u>some knowledge</u>, and whose role was either <u>responsible</u>, <u>approval</u>, or <u>implementor</u> remained in the list.
2. Assess the manager's understanding of each of the technologies and practices. From an initial list of integrated manufacturing technologies and practices, only those that the subject had at least "some knowledge" were used in the remainder of the interview. The initial list was compiled by this author through a literature review, and discussions with colleagues and

professors. Each subject was afforded the opportunity to add additional items to the list.

ROLE SYMBOL	DESCRIPTION
R	RESPONSIBLE: Actor takes initiative for developing alternatives, assuring consultation, analyzing situation, and perhaps making initial recommendation. Role ends upon approval decision.
A	APPROVE: Actor signs off on or vetoes decision before it is implemented, or chooses from alternatives developed as 'R' role.
C	CONSULT: Actor is consulted or asked for substantive input prior to sign off but has no veto power.
M	IMPLEMENT: Actor is informed of decision once it is made, but is not necessarily consulted before decision is made.
I	INFORM: Actor is informed of decision once it is made, but is not necessarily consulted before decision is approved.
X or Blank	NO ROLE: Actor has no role in decision.

Figure 6: **Responsibility Charting Roles**[57]

3. Score and rank order the remaining list of integrated technologies and practices <u>in terms of the most likely benefit to the productive unit's competitiveness if it were fully implemented</u>.

[57] From a technique for evaluating the decision-making process in organizations, from: Joseph E. McCann, and Thomas N. Gilmore, "Diagnosing Organizational Decision Making Through Responsibility Charting," Sloan Management Review (Winter 1983), p. 7.

4. Score and rank the same list <u>in terms of the most likely benefit to the manager's measured performance if implemented in the current manufacturing environment</u>.

The idea behind the phrases "if fully implemented", and "in the current manufacturing environment" in the 3rd and 4th parts of this phase was to lump together the effects of the corporate value system and management performance measures on the plant manager's behavior.

The last phase of the interview allowed each subject the opportunity to provide free-form input to the study in terms of his/her overall feeling regarding:

- Consistency of the messages sent from corporate management,
- A prescription for better coupling performance measures with competitive objectives, and
- Possible performance measures that would achieve the desired fit.

5.3 Proposed Quantitative Analysis

The analysis of the interview data was divided into three areas. These were:

1. A test of the appropriateness of the plant manager as the person most responsible for selecting and implementing integrated manufacturing technologies and practices.
2. Discussion of the productive unit's competitive objectives for each subject. This includes a discussion of the homogeneity of the subject population.
3. The quantitative and qualitative analysis of the interview data. Two levels of analysis were provided for.

The first level of analysis calls for the development of a "averaged" models for both the competitive scores and the personal performance scores. The two models are then compared to determine if they are statistically different using the Kolmogorov-Smirnov Two Sample[58] non-parametric test. This type of test assumes that the subject population is homogeneous. A test of homogeneity is the deviation of individual scores from the average model for the *competitive* data set.

The second level of analysis examines the number of dislocations in the pairs of scores for each subject. The list of integrated manufacturing technologies and practices is rank ordered, and split into three groups. The groups are then scrutinized to identify any commonality. For example, the technologies and practices that require long pay-back periods and/or are relatively capital intensive may fall in the second ranking (based on personal performance), regardless of how they support the productive unit's competitive objectives. If this occurs, it may be hypothesized that cost accounting measures are the primary performance issue.

[58] W.J. Conover, Practical Parametric Statistics. 2 ed. (New York:Wiley, 1980), p. 331.

6 Interpretation of Results

This section is describes the results from the pilot study including the analysis of interview data and insight gained through discussions with participating plant managers. It is organized as follows:

- The subject population is examined in terms of 1) *population of convenience* and 2) variance in *competitive objectives* data.
- Results from the responsibility charting phase of the interview are presented. The results suggest the role of the plant manager in the adoption of integrated manufacturing technologies and practices.
- The plant manager's propensity to adopt integrated manufacturing technologies and practices in investigated. Data from the pilot study are presented according to the analyses called for in the **Proposed Quantitative Analysis** section (see page 40).
- Findings from discussions with the participating plant managers are reviewed. These include the role of corporate staff organizations and three distinct management paradigms that may be used to describe the participant's companies.
- Implications for practicing managers and researchers are suggested.

6.1 Population of convenience

The subject population consisted of eleven manufacturing plant managers from five companies. Manufactured products and business environments varied greatly, but all of the productive units were involved in either continuous flow or repetitive manufacturing. In order to maintain the anonymity of the companies, all reporting is based on Standard Industry Classification **SIC** codes. The SIC codes represented in the subject population included:

SIC Code	Description	SUBJECT(S)
32xx	Ceramic Products	JJ, KK, LL
35xx	Machinery, except electrical	AA, BB, CC, EE, FF
36xx	Electrical & electrical equipment	DD, HH, II
38xx	Instruments & related products	GG

Figure 7: **Subject Population**

The population was not random. It was a *population of convenience.* The participating companies were those that offered easy entree, and were located geographically close (relatively) to the Lehigh University campus. The resulting data is heterogeneous, and does not represent a specific industry, market, or product type.

Because the data is heterogeneous, and because the sample population is small, statistical methods for calculating a mean distribution and variance of the responses would have little relevance. In fact, even if the population was large, a mean distribution would be meaningless to individual plant managers, because their competitive environments cannot be represented by an *average* market.

6.2 Productive Unit's Competitive Objectives

Figure eight depicts the participant's responses regarding the productive unit's competitive objectives. The large variance may be attributed to the heterogeneous subject population which included computer electronics manufacturers, a home appliance manufacturer, a distribution center for ceramic goods, and others. The scores in the figure were calculated by normalizing the combined scores which were generated using the formula:

COMBINED SCORE = (SCORE) * [(# of responses) + 1 - RANK]

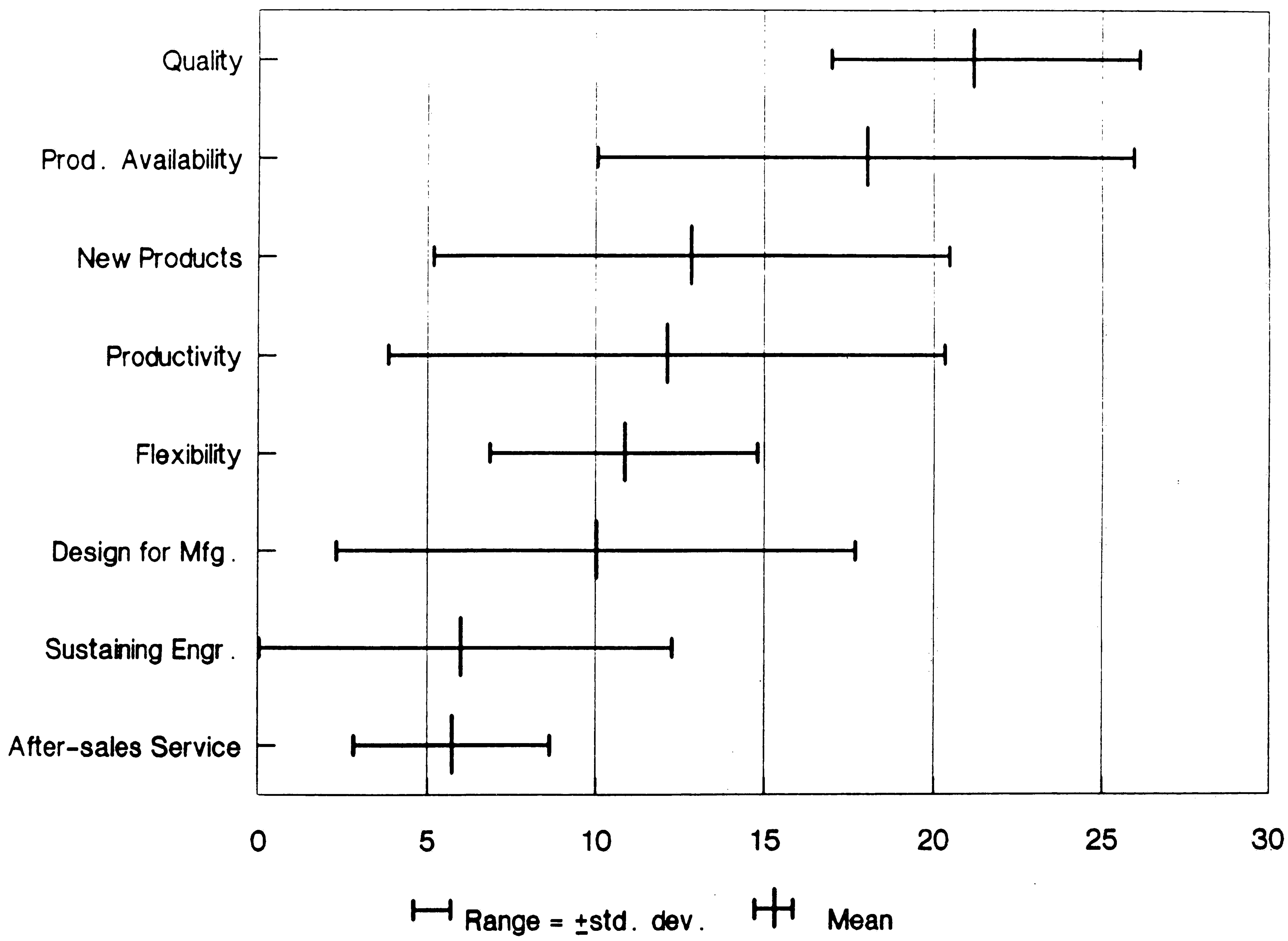

Figure 8: **Productive Unit's Competitive Objectives**

Recall the model presented in chapter three that described a situation where three management subsystems (financial reporting, value system, and management performance measures) determine the resulting manufacturing environment. Data from the pilot study suggests that within the management performance measures subsystem, Quality and Product Availability appear to be the most influential motivators in the plant manager's behavior. According to the model, quality and service may also be the keystones of the corporate value system, and thus mutually supportive. Cost analysis, based on financial reporting objectives, may support and justify an *acceptable quality level* that is contrary to the *total quality* philosophy. This scenario suggests that the model may be useful in describing competing priorities that may be present in an organization's infrastructure.

6.3 Plant Manager's Role in the Adoption Process

In large organizations, the responsibility of supporting the productive unit's competitive objectives can be buried in a labyrinth of matrixed organizational structures. For the purpose of this study, it was assumed that the person most responsible for adopting/implementing integrated manufacturing technologies and practices was the plant manager. In one of the participating companies, a plant manager's position did not exist. Instead, the director of manufacturing, who reported to a division vice president was interviewed. For the purpose of this study, the director of manufacturing at this company was synonymous with that of plant manager, and the title plant manager will be used generically throughout this thesis.

As a test of this assumption, each subject plant manager was asked to state what his or her role would be in the adoption process for each technology and practice. The set of role types shown in figure six was presented to the subject, and he/she was asked to select the one(s) that most closely reflected his/her role in the adoption process.

Some of the participants had difficulty responding to this part of the interview. Comments made by the subjects included:

- The director of manufacturing is "Accountable for implementation."
- The plant manager's role changes with the organization's maturity and his trust in his subordinates.
- The plant manager doesn't necessarily do the things himself, but accepts the responsibility.
- The decision doesn't rest with any one person.
- The plant manager has ultimate responsibility for implementation and as a *Champion* role.
- The plant manager has multiple roles - starts with responsible, and moves to implement - and is always accountable.

From these comments, it may be concluded that responsibility charting techniques may not be appropriate for determining a plant manager's overall role in the adoption process. However, the results shown in figure nine did serve to support the original proposition. The plant manager is the person most responsible for the adoption of integrated manufacturing technologies and practices, and therefore the most appropriate person to participate in the study.

The difficulty that several managers had in responding to this section of the interview may be due the dynamic nature of such decision-making. Mintzberg[59] has reported that there are three basic-decision making modes. These are:

- **Entrepreneurial**, where one strong leader takes bold, risky actions on behalf of his organization
- **Adaptive**, where the organization adapts in small, disjointed steps to a difficult environment

[59] Henry Mintzberg, "Strategy-Making in Three Modes," California Management Review, 16, No. 2 (1973), p. 44.

Technologies & Practices	R	A	M	C	I	X
Automated Material Handling	4	4	2			1
Automated Warehousing	4	4	1			1
Automatic Identification	4	4	2			1
Cell Manufacturing	3	3	1	2		1
Computer-Aided Design	2	4		1	2	1
Computer-Aided Process Planning	2	4	1	1		2
Computer Numerical Control	2	5	1	1		2
Design For Manufacturability	5	4	2	2		
Expert Systems	2	5	2	1		1
Flexible Manufacturing Systems	4	4	2			1
Incremental Process Improvements	2	4	2	1		2
Enhanced Cost Accounting	3	1		6	1	1
Just-In-Time Logistics	4	3	2	1	1	
Manufacturing Resource Planning	3	3	2	3		
New Materials & Processes	2	6	3	2	1	1
Preventatitive Maintenance	3	4	3	1		1
Robotics - Assembly	3	4	2	1		1
Robotics - Process	3	4	2	1		1
Total Quality Program	4	1	4	3	1	
TOTAL	59	71	34	27	6	18

R	Responsible
A	Approve
M	Implement
C	Consult
I	Inform
X	No Role

Figure 9: **Plant Manager's Role in the Adoption Process**

- **Planning**, where formal analysis is used to plan explicit, integrated strategies for the future

Mintzberg has suggested that a combination of all three modes can be used in an alternating pattern based on the specific decision, its organizational environment, and the decision horizon to effectively formulate strategy. The techniques used in the interview did not attempt to isolate these three modes of decision-making.

6.4 Competitive Objectives and the Resulting Manufacturing Environment

This section examines the dislocations in the pairs of scores (competitiveness and personal performance) for each participant, and each technology and practice. The objective of this analysis is to illustrate the relationship among the three management subsystems in our model (financial reporting, corporate value system and management performance measures), and the productive unit's competitive objectives.

Two levels of analysis are presented. The first attempts to quantify the extent to which the overall management system supports the competitiveness of the manufactured product. The second level sorts the technologies and practices according to the number of dislocations in the pars of scores and attempts to identify and describe any variance in the data.

6.4.1 First Level Analysis

The first level analysis calls for the development of averaged models for both competitive scores and performance scores. The two models would then be compared using the Kolmogorov-Smirnov test as described in section 5.3.

The data from the pilot study does not warrant this level of analysis due to the extreme variance exhibited in the Competitive Objectives reported by the participating plant managers. This variance may be explained by the population of convenience obtained for the study. In particular, the sample varies by

- Markets {Consumer products to computer hardware}
- Products {Silicon computer chips to television CRTs to Consumer appliances}

- Processes {Warehousing of stoneware to production of exotic silicon computer chips}
- Corporate culture and value system

6.4.2 Second Level Analysis

The second level of analysis attempts to identify and describe any interesting trends in the data. A spread sheet was constructed based on the differences in the normalized scores (How well the technology/practice would enhance the competitiveness of the productive unit minus how well it would enhance the plant manager's personal performance) for all participants, and technologies/practices.

A positive entry in any cell of the spreadsheet indicates that the participant believes the technology/practice would help the productive unit meet its competitive objectives MORE than it would enhance the plant manager's personal performance. For example, participant AA reported that implementing Cell Manufacturing would enhance competitiveness more than his own personal performance. The +/- column in figure ten indicates the ratio of participants who reported that <u>product competitiveness would be enhanced more than personal performance</u> to those who reported that <u>personal performance would be enhanced more than product competitiveness</u>. The technologies and practices in figure ten are rank ordered according to the +/- column.

In the top third of the data, the ratio is greater than two. In the bottom third of the figure, the ratio is less than one-half. One possible interpretation of the figure is that implementing the more popular technologies/practices (leading edge, current industry buzz words, etc.) would enhance personal performance more than product competitiveness. With some exceptions, the technologies/practices in the bottom third

	Competitiveness - Performance {Normalized Scores}	AA	BB	CC	DD	EE	FF	GG	HH	II	JJ	KK	LL	+/-
+	Enhanced Cost Accting Methods	3.18	-0.67	0.38	0.44	0.76			0.29					5/1
	Manufacturing Resource Planning	2.51	3.41	-0.81	6.16	0.88		0.64	1.46		-0.07	0.30		7/2
	Automatic Identification		2.70	0.24	1.29	0.34		-1.68	0.25	-2.04	3.69	1.03		7/2
	Automated Warehousing	0.77	-0.67	0.24	0.81	0.71			0.68	-0.57	0.92			6/2
	Computer-Aided Design	0.05		0.11		-0.36					2.46			3/1
	Computer Numerical Control			1.29	1.24	-0.34		1.01						3/1
	Cell Manufacturing	1.14	-0.67	1.16	2.45	0.36		1.91			-2.11	-6.11	39.26	6/3
0	New Materials & Processes	0.13		1.29		-0.32		-0.21	-2.08		2.80	2.38		4/3
	Automated Material Handling	0.67	-1.23	-0.68	-2.32	0.87		3.71	0.76	-1.49	2.30	2.52		5/4
	Computer-Aided Process Planning	2.10		-0.68		-4.40					2.00			2/2
	Preventative Maintenance Program		-0.67	0.11	-2.20	0.32			-1.17	17.47	-9.32	6.48	-8.02	4/5
	Robotics - Assembly	-1.56	3.27	-0.68	-0.02	0.33		0.17	-0.33	-13.61	3.38			4/5
	Robotics - Process	-1.53	-0.67	-0.68	-1.68	1.02		-0.93	2.85			2.10		3/5
–	Design for Manufacturability	-0.77	-2.04	0.24	-0.98	-0.38			-1.56	6.69	-1.01	2.53		3/6
	Incremental Process Improvments	-1.14	5.52	-0.54	-2.25	0.16		-1.02	-1.25	-2.15	-0.81	2.22		3/7
	Just-In-Time Logistics	-0.67	-2.13	-0.81	0.34	0.82		-1.39			-1.39	-2.28	-29.05	2/7
	Total Quality Control	-1.45	0.88	-0.95	-3.29	-0.40		-0.58	2.83		-1.49	-1.08	-2.19	2/8
	Expert Systems	-2.71	-0.27	0.38		-0.20			-0.19		-0.13	-2.93		1/6
	Flexible Manufacturing Systems	-0.72	-7.31	0.38		-0.19		-1.62	-2.53	-4.30	-1.21	-7.15		1/8

PRODUCT COMPETITIVENESS	HURT	NO EFFECT	ENHANCE
ENHANCE	STRONG +	+	0
NO EFFECT	+	0	-
HURT	0	-	STRONG -

PERSONAL PERFORMANCE

Figure 10: **Product Competitiveness vs. Manager's Performance {Detail}**

of the figure reflect the most current, popular industry buzz words. Conversely, the participating plant managers reported that mature technologies including Manufacturing Resource Planning, Automated Warehousing, and Computer Numerical Control would enhance product competitiveness more than his/her personal performance. This interpretation may be verified by examining the number of articles published on each technology/practice, or by examining the number of patents, technical disclosures and copyrights filed over time, or by plotting each item according to where it is along the technology lifecycle model. It seems unlikely that the latest, newest, technologies would provide the greatest benefit to the majority of the participating productive units. If this interpretation holds true, it would suggest that:

- The corporate value system is the most significant of the three management subsystems.
- Gannon's assertion[60] that managers may not be up to the job of managing technology may be justified.
- In the companies represented in the data, corporate management generally looks toward leading edge technology as a panacea, and the basis for meeting its competitive objectives.

Because the data represents a wide cross section of *all manufacturing*, it would be most interesting to find any consistencies throughout the data. Figure eleven demonstrates that, from the plant manager's perspective, the benefits derived from implementing integrated manufacturing technologies and practices generally support product competitiveness more than the plant manager's personal performance. Or, stated another way, the management system comprised of financial reporting, corporate value system, and management performance measures, is out of balance.

[60] Martin J. Gannon, "Managerial Ignorance," Business Horizons (May-June, 1983), p. 26.

	Competitiveness – Performance {Combined Scores}	No. of Responses	Ave. Competitiveness	Ave. Performance	Delta
+	Enhanced Cost Accting Methods	6	27.7	21.0	6.7
	Manufacturing Resource Planning	9	53.3	38.8	14.5
	Automatic Identification	9	36.7	28.7	8.0
	Automated Warehousing	8	28.0	23.0	5.0
	Computer-Aided Design	4	57.5	50.0	7.5
	Computer Numerical Control	4	57.8	50.8	7.0
	Cell Manufacturing	9	29.2	26.2	3.0
0	New Materials & Processes	7	58.3	51.1	7.2
	Automated Material Handling	10	36.1	25.5	10.6
	Computer-Aided Process Planning	4	34.0	36.3	-2.3
	Preventative Maintenance Program	9	28.2	31.2	-3.0
	Robotics - Assembly	9	31.6	27.1	4.5
	Robotics - Process	8	22.0	20.1	1.9
–	Design for Manufacturability	9	75.6	74.8	0.8
	Incremental Process Improvments	10	32.7	30.3	2.4
	Just-In-Time Logistics	9	72.4	75.7	-3.3
	Total Quality Control	10	82.2	81.6	0.6
	Expert Systems	7	32.1	37.3	-5.2
	Flexible Manufacturing Systems	9	45.9	58.6	-12.7
	TOTAL		841.3	788.1	53.2

Figure 11: **Product Competitiveness vs. Manager's Performance {Summary}**

The data suggests that the overall management system does send conflicting signals to the plant manager; the person most responsible for defining the manufacturing environment.

6.4.3 Conclusions from the Pilot Study

The model which was presented in chapter three is relevant in assessing the health of an organization's management system. The data suggests that an environment of conflicting priorities does exist for the plant manager. By balancing the emphasis on the three management subsystems and carefully defining the key management indicators used to assess the plant manager's performance, corporate management may ensure that the overall management system supports the competitive objectives of its product units. In any case, the data did exhibit a definite range and variance, which suggests an opportunity for further research.

In addition to formal interview data, conversations with the participating plant managers yielded two additional findings. The first pertains to the role of corporate staff organizations in the adoption of emerging technologies. The second pertains to the participant's descriptions of corporate management's changing attitude toward integrated manufacturing technologies and practices.

6.5 Corporate Staff Organizations

In all but one of the participating companies, a corporate staff person under the title *Director of Manufacturing* played one of the following roles in the adoption process:

- **Mentor** - A person who understands the opportunities of CIM and works toward convincing the plant managers to adopt these emerging technologies.
- **Champion** - Someone with no funding who plays a more active role in the adoption process, typically in a well bounded area, such as logistics, flexible manufacturing systems, or total quality.
- **Corporate Staff with seed money** - This money may be allocated to large projects that are too big for any one plant to support. Typically, once the project is complete, other plants may adopt the new system. The idea is to

allow the corporation to adopt a new technology or process, while having at least one plant accept partial risk in the adoption process.

- **Corporate Staff with full funding** - This money is used to support a single plant in the implementation of integrated manufacturing technologies and practices. The idea here is that the plant manager, whose compensation is based on profit & loss, and return on assets utilized, may not opt to invest in such technologies and practices. The corporate funding, in effect, acts to circumvent these management accounting measures.

In all cases, this person has the mission to ensure that manufacturing decisions are aligned with corporate goals and objectives. Wheelwright[61] has suggested that either the corporate manufacturing staff or line management can be effective in this role. Discussions with the participating plant managers suggest that these corporate staff are positioned to ensure consistency and synergy among the manufacturing plants.

Four of the five participating companies were comprised of multiple divisions and manufacturing plants, and each had a matrix-like organization where this responsibility was shared among line and staff personnel. In one case, the corporate staff had *seed money* for funding large projects that could benefit multiple plants. In another case, the corporate staff played the role of champion and convinced corporate management to accept that there are trade-offs associated with working to achieve long-term goals and short-term profit/loss objectives.

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[61] Steven C. Wheelwright, "Reflecting Corporate Strategy in Manufacturing Decisions," Business Horizons (February 1978), pp. 57(10).

6.6 Three Management Paradigms

Discussions with the participating plant managers suggested that there are three management paradigms a company will pass through. These are:

1. Management is rather well-entrenched, and manages the manufacturing arm of the business as though it were a "necessary evil." Management's emphasis is on cost reduction and "What's the competition doing?". This paradigm may be characterized as *Business as Usual* (Frederick Taylor division of work, etc.).
2. An outsider enters the market, e.g. the Pacific Rim, with quality products that are priced below those of the established competitors. Management looks toward technology as a panacea. Well-established cost accounting measures suggest that direct labor is a high-cost area that is responsible for cost and quality problems. This paradigm may be characterized as *Task Automation* through process automation and information systems.
3. Finally, when there are robots parked in the corner of the shop, and/or remnants of and the all-inclusive Manufacturing Resource Planning (MRP II) system are left on the company's host computer, management realizes that they have been reacting to the symptoms of their organization rather than addressing the underlying problems of complacency and lack of organizational agility. In order to successfully challenge the outsider's foothold in their markets, the organization will have to evolve to embrace the technology. Employees will need education and training. Power structures will change. The culture and value system will have to migrate from one that values adherence to specifications, order & control, and status quo, to one that embraces change, is market focused, and values incremental improvements in all activities. This paradigm may be characterized as *Business Process Automation* through

participative management, manufacturing excellence principles, and migration toward a corporate infrastructure that can take advantage of the strategic benefits of integrated manufacturing technologies and practices.

Wheelwright has reported that managerial strategies for manufacturing can be classified into four general categories:[62]

1. To minimize manufacturing's negative potential.
2. To achieve parity with competitors.
3. To provide credible support to the business strategy.
4. To pursue a manufacturing based competitive advantage.

The findings of the pilot study and Wheelwright's model are mutually supportive. As management's perspective of manufacturing evolves to embrace Manufacturing as a competitive weapon, Management will require the ability to evolve the manufacturing function to support the competitive objectives of the productive unit.

6.7 Implications of the Study

The pilot study may be used as the basis for developing a diagnostic tool for evaluating the appropriateness of performance measures. Such a tool would be particularly useful to consultants and senior management as they work to align management performance measures and the company's value system with the competitive objectives of productive units.

Such a diagnostic tool would have to take into consideration five key aspects of the environment, including

- Organizational Life cycle,

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[62] Steven C. Wheelwright, and Robert H. Hayes, "Competing Through Manufacturing," Harvard Business Review, 63, No. 1 (1985), p. 100.

- Product Life cycle,
- Technological sophistication of the product and manufacturing processes,
- Management Performance Measures, and
- Value System / Corporate Culture.

In support of such a tool, several of the plant managers that participated in the study stated that answering the questionnaire caused them to look at their decision-making in a different, perhaps more objective manner. One even remarked that he would have to re-think the direction he was taking regarding investments in technology.

Results from the study also suggest a course-of-action for researchers. Useful information for the design of a formal study was gained from the pilot study. For example, the pilot confirmed that the plant manager, when empowered, is the individual most responsible for the adoption of integrated manufacturing technologies and practices. In order to further this research area, it is proposed that a two-phase follow-on study be conducted. The first phase would be comprised of a mail-in questionnaire. The objective of the questionnaire would be to assess the line-of-business and organizational maturity of each plant manager's business unit, and to compile composite lists of <u>competitive areas</u> and <u>integrated technologies & practices</u>.

With this information, the subject population may be segregated by line-of-business, organizational maturity, and the three management paradigms regarding manufacturing's support of competitive objectives discussed elsewhere in this thesis.

The most homogeneous group of subjects may then be included in the second phase of the study. For example, one might suspect that for industries that support the same management paradigm, the disparity between how <u>they compete</u> and <u>how they measure performance</u> is a constant.

In order to test such a thesis, one would have to show statistically that the three groups (three paradigms) of subjects represent different populations.

By focusing on a particular line-of-business, organizational maturity, and/or management paradigm, non-parametric statistical analysis methods may be used to support the results.

The second phase of the formal study would be carried out in the same fashion as the pilot study. An additional step in the interview would be to have the subject rank order the given integrated manufacturing technologies and practices based on 1) time to fully implement, and 2) total cost of implementation.

In order to better understand the *art* of manufacturing, it is critical that the least common denominators of the environment are documented, generally understood, and measurable within manufacturing organizations. This research seeks to go beyond Abernathy's *Productive Unit*[63] so that management of technology principles can be applied consistently across manufacturing organizations showing each of the three management paradigms.

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[63] William J. Abernathy, Kim B. Clark, Industrial Renaissance: Producing a Competitive Future in America (New York: Harper and Row, 1983), ch. 2.

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8 Appendices

8.1 The GM - Saturn Example

This example of the Saturn Program describes the evolution of General Motors' management philosophy toward manufacturing technology, and demonstrates the following scenario:

1. Business as usual - in this case, an oligopoly.
2. An outsider enters the marketplace - in this case, Pacific Rim Automakers.
3. The initial response - Large investment in technology is seen as a panacea.
4. Management learns that technology alone is not the solution.
5. Management learns to manage people and technology in a evolutionary manner.

The evolution of the Saturn Program has been influenced by the problems encountered bringing the Hamtramck Plant on-line. Hamtramck is considered to be a state-of-the-art manufacturing facility.

The Saturn Program has also been influenced by the success of the New United Motors Incorporated (NUMMI) plant in Fremont, California. NUMMI is a joint venture between Toyota and General Motors. The Fremont Plant uses mature technology. Its superior productivity and quality are said to be a result of the management style/philosophy.

The Saturn corporation was started by General Motors as a method of circumventing existing corporate bureaucracy and functional boundaries, in developing and implementing emerging technologies in automobile manufacturing. Saturn quickly became GM's $5 billion dollar approach to meeting the import challenge and was thought to be the key to GM's long-term competitiveness.

Saturn is a tremendous example of how the global environment can influence the scope of a program, and how the program itself can act as a vehicle for organizational learning. GM has revised Saturn's marketing strategy as a result of a changing economic climate. Saturn's manufacturing strategy has evolved from one that stressed a technology intensive manufacturing environment to one that calls for a balance of automation technology and people management.

Saturn will be influenced by the lessons learned in developing the present family of GM automobiles and manufacturing plants. "What GM learned is that simply organizing work more effectively and giving workers more to say can produce more impressive results than millions of dollars worth of robots. With only a fraction of the money invested in GM's heavily robotized plants, Fremont [a joint venture with Toyota] is more efficient and produces better quality cars than any other plant in the GM system. Some internal GM studies have shown that poor quality already may be adding twenty percent to GM's cost because it would be cheaper to build them right than to fix them later."[64]

The methodology for describing Saturn's product-process will be to first present what is known about Saturn explicitly, and then to describe the predominant technological and managerial stepping stones in the evolution of the Saturn program.

Saturn - Eventually Saturn plans to build 500,000 cars per year in four models: two and four-door sedans, a two-door hatchback, and a two-seat sports coupe. The Saturn cars are being designed to be built in independent, self contained modules. These are: front-end module, rear-end module, wheel and tire module, and instrument panel module. Each module will be assembled and tested by a work team of 9-15 workers. The module method should make it easier for Saturn to build different types of vehicles, which are made up of common modules. Final assembly will involve simply

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[64] William J. Hampton, and James R. Norman, "General Motors: What Went Wrong," Business Week (March 16, 1987), p. 108.

fitting together the modules, which means that a mile-long assembly line won't be needed.

The Saturn manufacturing complex will eventually include assembly, engine and transaxle, stamping, forging, and plastic-molding plants.

"GM subsidiary Electronic Data Systems (EDS) is developing a computer network to help make Saturn a paper-less factory. The computers will be linked by manufacturing automation protocol (MAP) as much as possible." [65]

Hamtramck - The Detroit/Hamtramck plant which is part of the Buick-Oldsmobile- Cadillac (B-O-C) group, manufactures the Buick Riviera, Oldsmobile Toronado, and Cadillac Seville and Eldorado. The plant will also assemble the Cadillac Allante, whose body will be fabricated in Italy by Pininfarina.

One of the goals of the manufacturing site was to effectively control part logistics and the manufacturing process on a real-time basis and thus reduce work-in-process inventories while enhancing the flexibility of the manufacturing line. The plant stores only two to four hours worth of inventory and makes extensive use of bar coding to facilitate receiving and handling of parts.

> "Detroit/Hamtramck is among the first auto plants to use automatic vehicle identification (AVI) systems. This is a little black transponder made by Allen Bradley that is attached to the front of the car. The transponder sends out radio signals that are picked up by a receiver on the assembly line. The receiver then transmits a message to the plant's control system and host computer, which relay information back to the automated device. The information tells the device what model the car is, what color it should be painted, or where the sealant should be applied."[66]

Even with an extensive use of process automation, repair of improper welds and

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[65] "It's Now or Never for World-Class Automaking at GM," Iron Age, November 7, 1986.

[66] "How GM's Saturn Could Run Rings Around Old-Style Carmakers," Business Week, 28 January 1985, p. 126-128.

welds in areas that the robots have not been programmed to weld, eg. silicon bronze welds at the roof and front windshield area, are performed on a finesse line. "Most U.S. plant engineers still rely on such backup people or machines to correct errors made by automation."[67] The reason for these finesse lines are

- that automation of certain processes are not cost justified,
- process parameters are not well understood, and
- consistent quality is not attainable with present product designs and/or automation technology, eg. sensors, and robot controllers.

The implementation of the manufacturing floor control system hierarchy is the problem most reported in the literature. "GM continues to grapple with computer problems at its nine-month-old plant in Hamtramck, Michigan, which achieved only 70% of planned production levels. Observers blame Detroit's woes with automation on its assumption that technology alone would solve all problems. They're discovering that if you don't have good management, you'll end up with a rotten automated plant."[68]

New United Motors Manufacturing, Inc. - NUMMI is a joint venture between Toyota, and GM which is located in Fremont, California. The plant manufactures the Chevrolet Nova, and the Toyota model FX-16. "NUMMI is a test of the hypothesis that the Toyota Production System can successfully be modified and implemented in a U.S. automobile manufacturing plant that operates under a combination of Japanese and American management concepts."[69]

"NUMMI runs like a typical Toyota plant; Toyota was responsible for designing the manufacturing layout, buying the equipment, and implementing the production

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[67] "How GM's Saturn Could Run Rings Around Old-Style Carmakers," Business Week, (January 28, 1985), p. 126-128.

[68] ibid, p. 127.

[69] Mehran Sepehri, "Car Manufacturing Joint Venture Tests Feasibility of Toyota Method in U.S.," Industrial Engineering, 18, No. 3 (1986), p. 38.

system at Fremont. General Motors is responsible for marketing, and distributing the Chevrolet Nova."[70] The Toyota philosophy & production management concepts include:

- **Jidoka** - Line is stopped when abnormal condition is sensed.
- **Baka-Yoke** - Iterative optimization of machinery, labor utilization, and production methods by applying team suggestions.
- **Muda** - Eliminate waste in manufacturing.
- **Five Whys** - Ask "WHY' repeatedly until the root of a problem is discovered.
- **Heijunka** - Balanced utilization of all pertinent resources.
- **100% Quality** - Total Quality Program.
- **Standardized Work** - Tasks are organized in a routine manner.
- **Kanban** - Signboard system used to *pull* material through the manufacturing facility.
- **Small Lot** - Frequent delivery is used both from suppliers and within the facility.

NUMMI has become a symbol of manufacturing excellence achieved not just by installing leading technology, but by constant attention to detail. "NUMMI proved such a resounding success that today it is producing the highest quality cars in General Motors."[71]

The initial direction of the Saturn Program was the most aggressive ever taken on by a single company. It appeared that GM was going to install a lights-out factory with a completely integrated vendor network together with a newly designed car that could *snap together* ensuring perfect quality!

The lessons of NUMMI and Hamtramck have led Saturn to alter its original

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[70] Brian H. Berry, "What Makes the NUMMI Plant Different," Iron Age (September 5, 1986), p. 32.

[71] "It's Now or Never for World-Class Automaking at GM," Iron Age (November 7, 1986).

plan of using as much advanced technology as possible. As a result of NUMMI, Saturn is now more geared toward optimizing the human involvement in automation. "Just as NUMMI is a model Saturn would like to emulate, the problems at GM's Detroit/Hamtramck plant have warned Saturn of dangers in starting up too much technology all at once. The Hamtramck plant has trouble getting all its robots, automatic guided vehicles (AGVs), transponders and machine vision systems to work consistently together."[72]

Although the New United Motors Manufacturing Inc. plant uses mature technology to assemble Chevrolet Novas, its productivity is higher than most of GM's new plants. The key is Toyota's management style, which emphasizes thorough training and participative management, lean layers of middle management, and decision making pushed as much as possible to the assembly line. "NUMMI "Has shaken GM to the core," says David E. Cole [Director of the University of Michigan's Office for the Study of Automotive Transportation]. It's making them rethink their whole philosophy about how to be competitive."[73] GM has learned that automation technology alone cannot solve production problems. People are the key to the factory-of-the-future.

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[72] "It's Now or Never for World-Class Automaking at GM," Iron Age (November 7, 1987), p. 9.

[73] Russel Mitchell, "High Tech to the Rescue: More Than Ever, Industry is Pinning Its Hopes on Factory Automation," Business Week (June 16, 1986), p. 102.

8.2 Interview script and materials

Corporate Culture,
Management' Performance Measures
and the Adoption of
Integrated Manufacturing Technologies and Practices

name: ______________________________

date: ______________________________

position: ______________________________

company: ______________________________

location: ______________________________

L. O. B.: ______________________

SIC code: ______________________

- PRODUCT/MARKET SEGMENT (product, market, competitors)
- PRODUCTIVE UNIT (business unit, vendor network, product line & manufacturing/distribution network & field support.

- Confidentiality of detailed verses composite data
- Final report/thesis

I. Assessment of actual performance measures and competitive areas.

A. "How does Manufacturing support the competitive posture of the *productive unit*?" The objective here is to highlight how you compete and how you measure manager's performance.

1. Any additional areas? USE SHEET #1 (page 74)

- CARD DECK I -

2. Rate the importance of each activity with respect to the competitive position of the productive unit (1 - 7)
USE REFERENCE CARD #1 (page 77)
3. Rank order those activities within each score.
4. Is overall ranking acceptable?

5. How is the critical importance of the three top items translated into performance measures within the organization; say the functional level.

   How much are these performance measures stressed within your organization (on a scale of 1-10)?

   Are projects justified in terms that reflect these critical competitive areas?

   (talk about the difference between measures for which the manager has little or no control versus those that are not associated with how the productive unit competes.)

1. ______________________

2. ______________________

3. ______________________

II. Measurement of corporate culture and management performance measures relative to the adoption of integrated manufacturing technologies.

A. What integrated manufacturing technologies do you exert influence over?

1. Any additional items? USE SHEET #2 (page 75)

- CARD DECK II -

2. Indicate which best describes your role in the adoption of these integrated technologies and practices.
   USE REFERENCE CARD #2 (page 78)
3. What is your level of knowledge with regard to each item?
   USE REFERENCE CARD #3 (page 79)
4. Remove cards for items which the subject (1) has less than **Some Knowledge**, and (2) whose role is either **C - Consult, I - Inform, or X - No Role.**
5. Discuss organizational structure, with respect to decision process.

B. Score and rank order the remaining cards **in terms of most likely benefit to the <u>productive unit's competitiveness</u> if fully implemented.**

1. Score each item (1 - 7). <u>USE REFERENCE CARD #4</u> (page 80)
2. Rank order within each score.
3. Is the overall ranking acceptable?
4. **Break**

5. Create a new card deck for the next step.
6. Review the first phase of the interview.

C. Score and rank order the card deck **in terms of most likely benefit to the manager's measured performance if implemented in the current manufacturing environment {culture & value system}.**

1. Score each item (1 - 7). USE REFERENCE CARD #5 (page 81)
2. Rank order within each score.
3. Is the overall ranking acceptable?

III. This last phase of the interview will attempt to ascertain the likelihood of better aligning the competitive areas of the productive unit with internal managers' performance measures. (If the first two phases were descriptive, then this phase can be thought of as prescriptive.)

A. Do you feel that your subordinate managers' performance measures are tightly coupled to the competitive environment? (talk about long verses short term horizon).

B. What would have to happen in order to better couple performance measures with how the productive unit competes?

1. List items and then score them on the basis of likelihood of them occurring, being adopted, etc.

USE REFERENCE CARD #6 (page 82)

C. What performance measures would better couple the signals to managers with the competitive environment?

8.2.1 List of Competitive Areas

1. In what areas does Manufacturing contribute to the competitive position of the productive unit?

AFTER-SALES SERVICE Configuration management, spare parts, etc.	
COST EFFECTIVENESS By Design for Manufacturability	
COST EFFECTIVENESS By productivity within Manufacturing	
FLEXIBILITY Level of customization & featurization	
NEW PRODUCT INTRODUCTIONS	
PRODUCT AVAILABILITY Order turn-around-time	
QUALITY SPQL and early life failures	
SUSTAINING ENGINEERING Product improvements, Product line extensions	

8.2.2 List of Integrated Technologies & Practices

2. With regard to adoption/implementation decisions, what integrated manufacturing technologies and practices would you exert influence over? Do you have any additions to this list?

AUTOMATED MATERIAL HANDLING Conveyers, Car-on-track systems, AGVs, etc.	
AUTOMATED WAREHOUSING AS/RS, Carrousels, etc.	
AUTOMATIC IDENTIFICATION Bar coding, Magnetic strip	
CELL MANUFACTURING & GROUP TECHNOLOGY	
COMPUTER-AIDED DESIGN & DRAFTING	
COMPUTER-AIDED PROCESS PLANNING Generative & Retrieval	
COMPUTER & DISTRIBUTED NUMERICAL CONTROL CNC & DNC; also Computer-Aided Manufacturing	
DESIGN FOR MANUFACTURABILITY & ZERO DEFECTS	
EXPERT SYSTEMS DEVELOPMENT Test & debug procedures, etc.	
FLEXIBLE MANUFACTURING SYSTEMS	
INCREMENTAL PROCESS IMPROVEMENTS ie. welding, circuit board wet processes	
INNOVATIVE COST ACCOUNTING PROCEDURES & MEASURES	
JUST-IN-TIME LOGISTICS	
MANUFACTURING RESOURCE PLANNING (MRP II)	

NEW MATERIALS & PROCESS TECHNOLOGIES Substituting new for old	
PREVENTATIVE MACHINE MAINTENANCE PROGRAM	
ROBOTICS - ASSEMBLY	
ROBOTICS - PROCESS Welding, deburring, machine loading, etc.	
TOTAL QUALITY PROGRAM	

1.

Score these Competitive areas in terms of importance to the competitive position of the Productive Unit.

1 – Insignificant Importance
2 –
3 – Minor Importance
4 –
5 – Significant Importance
6 –
7 – Major Importance

2.

Which best describes your role in the adoption of these integrated technologies and practices?

R – Responsible **Takes initiative for developing alternatives, assuring consultation, analyzing situation, and perhaps making initial recommendation. Role ends with approval of decision.**

A – Approve **Signs off on or vetoes decision before it is implemented, or chooses from alternatives developed by the "R" role.**

C – Consult **Consulted or asked for substantive input prior to sign off but has no veto power.**

M – Implement **Held accountable for implementation of decision once it is made.**

I – Inform **Informed of decision once it is made, but is not necessarily consulted before the decision is approved.**

X – No Role **No role in the decision process.**

3.

What is your level of understanding of each technology/ practice in terms of what it does (as opposed to how it works)?

1 – No Knowledge
2 – Awareness
3 – Interest
4 – Some Knowledge **(Read some articles, attended a conference or seminar)**
5 – Knowledgeable
6 – Expert

4.

Score these integrated technologies and practices in terms of most likely benefit to the productive unit's competitiveness if fully implemented.

1 – Insignificant Benefit
2 –
3 – Minor Benefit
4 –
5 – Significant Benefit
6 –
7 – Major Benefit

5.

Score these integrated technologies and practices in terms of most likely benefit to the manager's measured performance if implemented in the current manufacturing environment {culture and value system}.

1 – Insignificant Benefit
2 –
3 – Minor Benefit
4 –
5 – Significant Benefit
6 –
7 – Major Benefit

6.

Score each item with respect to the likelihood of it occuring, being adopted, etc. within a two year window.

1 – Not Possible
2 –
3 – Doubtful
4 –
5 – Likely
6 –
7 – Assured

8.3 Data

FORMULAS

Given: α = SCORE

β = RANK

σ = No. of Qualified Responses

CS = COMBINED SCORE = $\alpha(\sigma + 1 - \beta)$

$$NS = \text{NORMALIZED SCORE} = \frac{CS}{\sum_{n=1}^{\sigma} CS_n} * 100\%$$

$$DELTA = \frac{NS_M - NS_P}{NS_M} * 100\%$$

Where: NS_M = NS (Product's Performance in the Market)

NS_P = NS (Manager's Performance)

DELTA is defined as the dysfunctional emphasis put on a given technology that is attributable to management performance measures

SUBJECT AA

	@	MARKET NEED CS	MARKET NEED NS	PERFORMANCE CS	PERFORMANCE NS	DELTA
Automated Material Handling	5	12	1.4	6	0.8	-47.1
Automated Warehousing	5	16	1.9	9	1.1	-40.5
Automatic Identification	4		0.0		0.0	
Cell Manufacturing	5	35	4.2	24	3.0	-27.5
Computer-Aided Design	5	48	5.7	45	5.6	-0.8
Computer-Aided Process Planning	4	60	7.1	40	5.0	-29.5
Computer Numerical Control	4		0.0		0.0	
Design for Manufacturability	5	112	13.3	112	14.1	5.8
Expert Systems	5	66	7.8	84	10.5	34.6
Flexible Manufacturing Systems	5	105	12.5	105	13.2	5.8
Incremental Process Improvements	4	20	2.4	28	3.5	48.1
Enhanced Cost Accounting Methods	4	30	3.6	3	0.4	-89.4
Just-In-Time Logistics	5	98	11.6	98	12.3	5.8
Manufacturing Resource Planning	5	91	10.8	66	8.3	-23.3
New Materials & Processes	4	54	6.4	50	6.3	-2.1
Preventative Maintenance Program	3		0.0		0.0	
Robotics - Assembly	4	8	0.9	20	2.5	164.4
Robotics - Process	4	4	0.5	16	2.0	323.1
Total Quality Program	4	84	10.0	91	11.4	14.6

@ Manager's Knowledge

Average DELTA 53.9

SUBJECT BB

	@	MARKET NEED CS	MARKET NEED NS	PERFORMANCE CS	PERFORMANCE NS	DELTA
Automated Material Handling	4	12	1.7	22	2.9	73.1
Automated Warehousing	5	16	2.3	22	2.9	29.8
Automatic Identification	4	40	5.6	22	2.9	-48.1
Cell Manufacturing	5	16	2.3	22	2.9	29.8
Computer-Aided Design	2		0.0		0.0	
Computer-Aided Process Planning	3		0.0		0.0	
Computer Numerical Control	2		0.0		0.0	
Design for Manufacturability	6	78	11.0	98	13.0	18.6
Expert Systems	4	50	7.0	55	7.3	3.9
Flexible Manufacturing Systems	5	16	2.3	72	9.6	324.9
Incremental Process Improvements	4	60	8.4	22	2.9	-65.4
Enhanced Cost Accounting Methods	4	16	2.3	22	2.9	29.8
Just-In-Time Logistics	6	84	11.8	105	13.9	18.0
Manufacturing Resource Planning	5	45	6.3	22	2.9	-53.8
New Materials & Processes	1		0.0		0.0	
Preventative Maintenance Program	5	16	2.3	22	2.9	29.8
Robotics - Assembly	4	44	6.2	22	2.9	-52.8
Robotics - Process	6	16	2.3	22	2.9	29.8
Strategic Planning		112	15.8	112	14.9	-5.6
Total Quality Program	5	90	12.7	91	12.1	-4.5

@ Manager's Knowledge

Average DELTA 50.8

SUBJECT CC	@	MARKET NEED CS	MARKET NEED NS	PERFORMANCE CS	PERFORMANCE NS	DELTA
Automated Material Handling	5	5	4.6	5	5.3	14.7
Automated Warehousing	5	6	5.5	5	5.3	-4.4
Automatic Identification	5	6	5.5	5	5.3	-4.4
Cell Manufacturing	5	7	6.4	5	5.3	-18.0
Computer-Aided Design	4	7	6.4	6	6.3	-1.7
Computer-Aided Process Planning	5	5	4.6	5	5.3	14.7
Computer Numerical Control	4	6	5.5	4	4.2	-23.5
Design for Manufacturability	5	6	5.5	5	5.3	-4.4
Expert Systems	4	5	4.6	4	4.2	-8.2
Flexible Manufacturing Systems	5	5	4.6	4	4.2	-8.2
Incremental Process Improvements	4	4	3.7	4	4.2	14.7
Enhanced Cost Accounting Methods	5	5	4.6	4	4.2	-8.2
Just-In-Time Logistics	5	6	5.5	6	6.3	14.7
Manufacturing Resource Planning	5	6	5.5	6	6.3	14.7
New Materials & Processes	4	6	5.5	4	4.2	-23.5
Preventative Maintenance Program	5	7	6.4	6	6.3	-1.7
Robotics - Assembly	5	5	4.6	5	5.3	14.7
Robotics - Process	5	5	4.6	5	5.3	14.7
Total Quality Program	5	7	6.2	7	7.4	14.7

@ Manager's Knowledge

Average DELTA 11.8

SUBJECT DD		MARKET NEED		PERFORMANCE		DELTA
	@	CS	NS	CS	NS	
Automated Material Handling	4	16	2.7	28	5.0	85.4
Automated Warehousing	4	9	1.5	4	0.7	-52.9
Automatic Identification	4	50	8.5	40	7.2	-15.3
Cell Manufacturing	4	24	4.1	9	1.6	-60.3
Computer-Aided Design	3		0.0		0.0	
Computer-Aided Process Planning	2		0.0		0.0	
Computer Numerical Control	4	20	3.4	12	2.2	-36.4
Design for Manufacturability	5	98	16.6	98	17.6	5.9
Expert Systems	1		0.0		0.0	
Flexible Manufacturing Systems	2		0.0		0.0	
Incremental Process Improvements	4	45	7.6	55	9.9	29.5
Enhanced Cost Accounting Methods	4	28	4.7	24	4.3	-9.2
Just-In-Time Logistics	5	91	15.4	84	15.1	-2.2
Manufacturing Resource Planning	4	84	14.2	45	8.1	-43.3
New Materials & Processes	3		0.0		0.0	
Preventative Maintenance Program	4	40	6.8	50	9.0	32.4
Robotics - Assembly	4	2	0.3	2	0.4	5.9
Robotics - Process	4	6	1.0	15	2.7	164.8
Total Quality Program	4	77	13.1	91	16.3	25.2

@ Manager's Knowledge

Average DELTA 40.6

SUBJECT EE	@	MARKET NEED CS	MARKET NEED NS	PERFORMANCE CS	PERFORMANCE NS	DELTA
Automated Material Handling	5	20	1.6	9	0.8	-53.3
Automated Warehousing	5	15	1.2	6	0.5	-58.5
Automatic Identification	5	54	4.4	48	4.0	-7.8
Cell Manufacturing	5	48	3.9	42	3.5	-9.3
Computer-Aided Design	5	119	9.7	119	10.0	3.7
Computer-Aided Process Planning	5	8	0.6	60	5.0	677.8
Computer Numerical Control	5	112	9.1	112	9.4	3.7
Design for Manufacturability	5	126	10.2	126	10.6	3.7
Expert Systems	5	66	5.4	66	5.6	3.7
Flexible Manufacturing Systems	5	35	2.8	36	3.0	6.7
Incremental Process Improvements	4	4	0.3	2	0.2	-48.1
Enhanced Cost Accounting Methods	6	84	6.8	72	6.1	-11.1
Just-In-Time Logistics	5	91	7.4	78	6.6	-11.1
Manufacturing Resource Planning	6	98	7.9	84	7.1	-11.1
New Materials & Processes	5	105	8.5	105	8.8	3.7
Preventative Maintenance Program	4	60	4.9	54	4.5	-6.7
Robotics - Assembly	4	30	2.4	25	2.1	-13.6
Robotics - Process	5	25	2.0	12	1.0	-50.2
Total Quality Program	6	133	10.8	133	11.2	3.7

@ Manager's Knowledge

Average DELTA 52.0

SUBJECT FF

	@	MARKET NEED CS	NS	PERFORMANCE CS	NS	DELTA
Automated Material Handling			.		.	.
Automated Warehousing			.		.	.
Automatic Identification			.		.	.
Cell Manufacturing			.		.	.
Computer-Aided Design			.		.	.
Computer-Aided Process Planning			.		.	.
Computer Numerical Control			.		.	.
Design for Manufacturability			.		.	.
Expert Systems			.		.	.
Flexible Manufacturing Systems			.		.	.
Incremental Process Improvements			.		.	.
Enhanced Cost Accounting Methods			.		.	.
Just-In-Time Logistics			.		.	.
Manufacturing Resource Planning			.		.	.
New Materials & Processes			.		.	.
Preventative Maintenance Program			.		.	.
Robotics - Assembly			.		.	.
Robotics - Process			.		.	.
Total Quality Program			.		.	.

@ Manager's Knowledge

Average DELTA .

This subject was not able to complete the interview due to schedule difficulties.

SUBJECT GG

	@	MARKET NEED CS	NS	PERFORMANCE CS	NS	DELTA
Automated Material Handling	4	80	8.3	40	4.6	-44.4
Automated Warehousing	4	50	5.2	45	5.2	0.0
Automatic Identification	5	75	7.8	82	9.5	21.5
Cell Manufacturing	4	85	8.9	60	7.0	-21.6
Computer-Aided Design	3		0.0		0.0	
Computer-Aided Process Planning	2		0.0		0.0	
Computer Numerical Control	4	93	9.7	75	8.7	-10.4
Design for Manufacturability	3		0.0		0.0	
Expert Systems	3		0.0		0.0	
Flexible Manufacturing Systems	5	40	4.2	50	5.8	38.9
Incremental Process Improvements	4	88	9.2	88	10.2	11.1
Enhanced Cost Accounting Methods	2		0.0		0.0	
Just-In-Time Logistics	4	90	9.4	93	10.8	14.8
Manufacturing Resource Planning	5	95	9.9	80	9.3	-6.4
New Materials & Processes	4	98	10.2	90	10.4	2.1
Preventative Maintenance Program	3		0.0		0.0	
Robotics - Assembly	4	35	3.6	30	3.5	-4.8
Robotics - Process	4	30	3.1	35	4.1	29.6
Total Quality Program	5	100	10.4	95	11.0	5.6

@ Manager's Knowledge

Average DELTA 16.2

SUBJECT HH

	@	MARKET NEED CS	MARKET NEED NS	PERFORMANCE CS	PERFORMANCE NS	DELTA
Automated Material Handling	6	60	9.3	50	8.5	-8.1
Automated Warehousing	6	54	8.4	45	7.7	-8.1
Automatic Identification	5	6	0.9	4	0.7	-26.5
Cell Manufacturing	4		0.0		0.0	
Computer-Aided Design	4		0.0		0.0	
Computer-Aided Process Planning	3		0.0		0.0	
Computer Numerical Control	4		0.0		0.0	
Design for Manufacturability	5	98	15.2	98	16.8	10.3
Expert Systems	4	12	1.9	12	2.1	10.3
Flexible Manufacturing Systems	5	84	13.0	91	15.6	19.4
Incremental Process Improvements	6	25	3.9	30	5.1	32.3
Enhanced Cost Accounting Methods	5	3	0.5	1	0.2	-63.2
Just-In-Time Logistics	5		0.0		0.0	
Manufacturing Resource Planning	6	48	7.4	35	6.0	-19.6
New Materials & Processes	6	66	10.2	72	12.3	20.3
Preventative Maintenance Program	5	20	3.1	25	4.3	37.8
Robotics - Assembly	6	42	6.5	40	6.8	5.0
Robotics - Process	6	36	5.6	16	2.7	-51.0
Total Quality Program	6	91	14.1	66	11.3	-20.0

@ Manager's Knowledge

Average DELTA 23.7

SUBJECT II	@	MARKET NEED CS	NS	PERFORMANCE CS	NS	DELTA
Automated Material Handling	4	24	14.6	25	16.1	10.2
Automated Warehousing	4	16	9.8	16	10.3	5.8
Automatic Identification	4	3	1.8	6	3.9	111.6
Cell Manufacturing	4		0.0		0.0	
Computer-Aided Design	4		0.0		0.0	
Computer-Aided Process Planning	3		0.0		0.0	
Computer Numerical Control	2		0.0		0.0	
Design for Manufacturability	4	48	29.3	35	22.6	-22.8
Expert Systems	3		0.0		0.0	
Flexible Manufacturing Systems	4	12	7.3	18	11.6	58.7
Incremental Process Improvements	4	6	3.7	9	5.8	58.7
Enhanced Cost Accounting Methods	4		0.0		0.0	
Just-In-Time Logistics	3		0.0		0.0	
Manufacturing Resource Planning	2		0.0		0.0	
New Materials & Processes	4		0.0		0.0	
Preventative Maintenance Program	4	35	21.3	6	3.9	-81.9
Robotics - Assembly	4	20	12.2	40	25.8	11.6
Robotics - Process	3		0.0		0.0	
Total Quality Program	5		0.0		0.0	

@ Manager's Knowledge

Average DELTA 57.7

SUBJECT JJ

		MARKET NEED		PERFORMANCE		DELTA
	@	CS	NS	CS	NS	
Automated Material Handling	4	77	8.5	50	6.2	-27.2
Automated Warehousing	4	70	7.7	55	6.8	-11.9
Automatic Identification	4	84	9.2	45	5.5	-40.0
Cell Manufacturing	4	20	2.2	35	4.3	96.1
Computer-Aided Design	4	56	6.2	30	3.7	-40.0
Computer-Aided Process Planning	4	63	6.9	40	4.9	-28.8
Computer Numerical Control	2		0.0		0.0	
Design for Manufacturability	5	30	3.3	35	4.3	30.7
Expert Systems	5	10	1.1	10	1.2	12.1
Flexible Manufacturing Systems	4	91	10.0	91	11.2	12.1
Incremental Process Improvements	4	15	1.6	20	2.5	49.4
Enhanced Cost Accounting Methods	5		0.0		0.0	
Just-In-Time Logistics	5	105	11.5	105	12.9	12.1
Manufacturing Resource Planning	5	5	0.5	5	0.6	12.1
New Materials & Processes	4	49	5.4	21	2.6	-52.0
Preventative Maintenance Program	5	25	2.7	98	12.1	339.3
Robotics - Assembly	4	98	10.8	60	7.4	-31.4
Robotics - Process	4		0.0		0.0	
Total Quality Program	5	112	12.3	112	13.8	12.1

@ Manager's Knowledge

Average DELTA 50.5

SUBJECT KK

	@	MARKET NEED CS	NS	PERFORMANCE CS	NS	DELTA
Automated Material Handling	4	35	6.4	20	3.9	-39.2
Automated Warehousing	2		0.0		0.0	
Automatic Identification	4	12	2.2	6	1.2	-46.8
Cell Manufacturing	4	4	0.7	35	6.8	831.5
Computer-Aided Design	3		0.0		0.0	
Computer-Aided Process Planning	2		0.0		0.0	
Computer Numerical Control	2		0.0		0.0	
Design for Manufacturability	4	84	15.4	66	12.9	-16.4
Expert Systems	4	16	2.9	30	5.9	99.6
Flexible Manufacturing Systems	5	25	4.6	60	11.7	155.5
Incremental Process Improvements	4	60	11.0	45	8.8	-20.2
Enhanced Cost Accounting Methods	3		0.0		0.0	
Just-In-Time Logistics	4	77	14.2	84	16.4	16.1
Manufacturing Resource Planning	4	8	1.5	6	1.2	-20.2
New Materials & Processes	4	30	5.5	16	3.1	-43.2
Preventative Maintenance Program	5	48	8.8	12	2.3	-73.4
Robotics - Assembly	2		0.0		0.0	
Robotics - Process	4	54	9.9	40	7.8	-21.1
Total Quality Program	5	91	16.7	91	17.8	6.5

@ Manager's Knowledge

Average DELTA 106.9

SUBJECT LL

	@	MARKET NEED CS	NS	PERFORMANCE CS	NS	DELTA
Automated Material Handling			0.0		0.0	
Automated Warehousing			0.0		0.0	
Automatic Identification	2		0.0		0.0	
Cell Manufacturing	4	24	46.2	4	6.9	-85.1
Computer-Aided Design	2		0.0		0.0	
Computer-Aided Process Planning			0.0		0.0	
Computer Numerical Control	2		0.0		0.0	
Design for Manufacturability	3		0.0		0.0	
Expert Systems			0.0		0.0	
Flexible Manufacturing Systems			0.0		0.0	
Incremental Process Improvements			0.0		0.0	
Enhanced Cost Accounting Methods			0.0		0.0	
Just-In-Time Logistics	5	10	19.2	28	48.3	151.0
Manufacturing Resource Planning	2		0.0		0.0	
New Materials & Processes	3		0.0		0.0	
Preventative Maintenance Program	4	3	5.8	8	13.8	139.1
Robotics - Assembly			0.0		0.0	
Robotics - Process	2		0.0		0.0	
Total Quality Program	6	15	28.8	18	31.0	7.8

@ Manager's Knowledge — Average DELTA 95.7

VITA

Mr. Robert Steven Goppold is the oldest son of Victor and Margo Goppold, and was born in Jersey City, New Jersey on November 30, 1957. After attending Northern Valley Regional High School in Demarest, New Jersey, Mr. Goppold completed a BS degree in Mechanical Engineering from Drexel University in Philadelphia, Pennsylvania. He graduated in June, 1984 and then worked for IBM in Endicott, New York as an Advanced Manufacturing Engineer. While at IBM, he was a member of a core team responsible for developing the manufacturing environment for future intermediate computer CPUs.

Mr. Goppold was granted an academic leave of absence in the fall of 1986 to pursue a MS degree in Manufacturing Systems Engineering at Lehigh University. His education was funded, in part, through a grant from the Pennsylvania Ben Franklin Advanced Technology Center. During his one and one-half year stay at Lehigh, he worked half-time as a Research Assistant for the Center for Design and Manufacturing Innovation. He completed all course-work requirements for the degree in December, 1987.

In January, 1988, Mr. Goppold accepted employment with Ernst & Young as a Manufacturing Consultant in Philadelphia, Pennsylvania.